A Text Book of BIOLOGY

II

KUNDU
GUHA
DAS

A TEXT BOOK OF BIOLOGY

PART TWO

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PREFACE TO THE THIRD EDITION

The third edition of the part II of the Text Book of Biology has been received cordially by students and teachers, to whom we express our sincere thanks.

In the third edition the general arrangement and content of the book have not been altered appreciably, but some improvements have been made so that this book will be more useful to all.

We would respectfully request the learned teachers for any suggestion they would like to make for the improvement of the book.

It is our pleasure to express our appreciation to Sri Tapan Kumar Barik and staffs of the Ajanta Printers for printing the book within a short time in spite of various difficulties.

Calcutta,
July, 1980.

B. C. Kundu.
S. Guha.
S. K. Das.

PREFACE TO THE FIRST EDITION

The present course forms the second part of our Text Book of Biology meant for the XII classes of Schools and Colleges under the Council of Higher Secondary Board, West Bengal. As in Part I, in Part II also, the authors have included some subjects to be studied by students of plus two classes of the I.S.C.E. and similar Boards. The subject matters have been so arranged that this book can be conveniently used for different types of courses.

As in the case of Part I, in Part II also each chapter has been carefully examined by experienced teachers and specialists in different subjects.

Physiology is a new subject for the XII classes of Schools and Colleges under the Council of Higher Secondary Board, West Bengal. Physiology is not only helpful for the specialisation in Medical

Sciences but also its implementation in day-to-day life is of vital importance for leading a better life. Thus careful attention has been given to easy understanding of this subject with a view to making an interest to read Physiology as a basic science. Some portions in this edition is rewritten to make it up-to-date.

We take this opportunity of expressing our deep gratitude to Sm. Kalpana Ghosh, teacher in Biology, Madhyamgram Girls School and Dr. L. K. Das, Entomology Division, Jute Agri. Res. Inst., Barrackpore for their interest in the writing up this second part. We are grateful to Dr. D. N. Roy Choudhury, Department of Zoology, Calcutta University, Dr. V. G. Jhingran, Director, Central Inland Fisheries, Barrackpore; Dr. Naresh Ch. Dutta, Department of Zoology, Calcutta University; Dr. Surakali Ghosh, Entomology Dept., Bidhan Chandra Krishi Viswa Vidyalaya and Dr. G. G. Kundu, Senior Entomologist, Indian Agricultural Research Institute, New Delhi, who helped us materially in the improvement of the text.

Thanks are also due to Sri Panchanan De, Lecturer in Botany, Uluberia College and Sri V. L. Kalyane, Senior Research Fellow, I.C.A.R. who have also helped us in various ways.

Thanks to Dr. S. Chatterjee, Ph. D., and Dr. (Mrs.) P. Chatterjee, Ph. D., Lecturers in Physiology, Calcutta University who helped us not only with materials but also encouraged us to write the manuscript. We are also grateful to Dr. C. Deb, Ph.D., Prof. & Head, Department of Physiology, Calcutta University for his encouragement in writing up the manuscript of the Physiology portion. We are grateful to some of the teachers who taught class XII and criticized us to improve this revision as per students best understanding.

We are also grateful to Sri Bimal Kr. Sarkar who has typed and assembled the manuscript. It is our pleasure to express our appreciation to Sri Tapan Kumar Barik and other staff members of the Ajanta Printers for printing the book within a short time.

It is our pleasure to record the help received from Shri Sudip Chakravorty, Librarian, Industrial Section, Botanical Survey of India and Sm. Namita Sen, Librarian, Zoological Survey of India. The help of Mrs. Kalpana Das, Science teacher of Lady Abala Bose Balika Vidyalaya, is appreciated.

B. C. Kundu.
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BOTANY

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VIRUS

The term *virus*, was used for many years to denote a poison or contagion of infectious diseases. When the pathogenic bacteria were discovered they were often referred to as the 'viruses'. It was first used in its modern sense by Louis Pasteur who applied it to agents that were not bacteria, but associated with diseases. They are a unique class of infectious agents having truly distinctive features which lie in their structure, composition and mechanism of replication. Their presence is revealed only when they produce certain diseased conditions in the plant or in the animal. They are of great importance as causative agents for small pox, chicken pox, measles, German measles, mumps, influenza, colds, infectious hepatitis, jaundice, yellow fever, polio and rabies. It is known that viruses cause cancer and cancer-like growths in plants and animals. After virus infection plant and animal cells continue to divide adnormally resulting in abnormal proliferation of host cells. Such abnormal growths are called *tumors or neoplasms*. In man skin, laryngial or other types of warts are caused by viruses. In recent times, it has been postulated that viruses are a cause of cancer in humans.

Virus may be defined as the smallest sub-microscopic and possibly the most primitive living organisms having no cellular structure. They do not fit easily into any of the traditional groups into which living organisms are classified. Some biologists, therefore, treat them separately as *acellular* organisms in comparison to the cellular organisms, that is, plants and animals. They cannot be detected even under the most powerful light microscope. As a result of special electron microscopic technique, the structure of viruses can be worked out.

Mayer in 1836 first described the virus disease of tobacco plant and called it tobacco mosaic. In 1892 Ivanwoski, a Russian Biologist working on the mosaic disease of the tobacco plant, proved that the sap from a diseased plant even when passed through bacteria proof porcelain filter (i.e. a filter through which bacteria cannot pass) was capable of inducing mosaic disease in the healthy tobacco plant. In 1899 the Dutch microbiologist, Veijevineck working also on the tobacco mosaic found the same result as found by Ivanwoski and he designated this as '*Contagium vivum fluidum*' and later as virus.

Structure—Viruses are acellular, that is, have no cellular structure. They are complex organisms having a genetic mechanism. A complete virus particle, called a *virion*, is a block of genetic material, either DNA or RNA (never both as in bacteria), surrounded by a shell, that is, an outer protective coat of protein which is called *capsid*. They are of varying shapes and sizes ranging in length from 10 mμ to 350 mμ, sometimes upto 450 mμ. (1 mμ = 1/1000 μ). The shell which serves as a protective jacket, is in certain cases used as a means for breaking the wall of the host cell to be infected. Besides nucleic acid and protein, lipid, polysaccharides, copper, biotin, flavin, etc. may be found in some animal viruses.

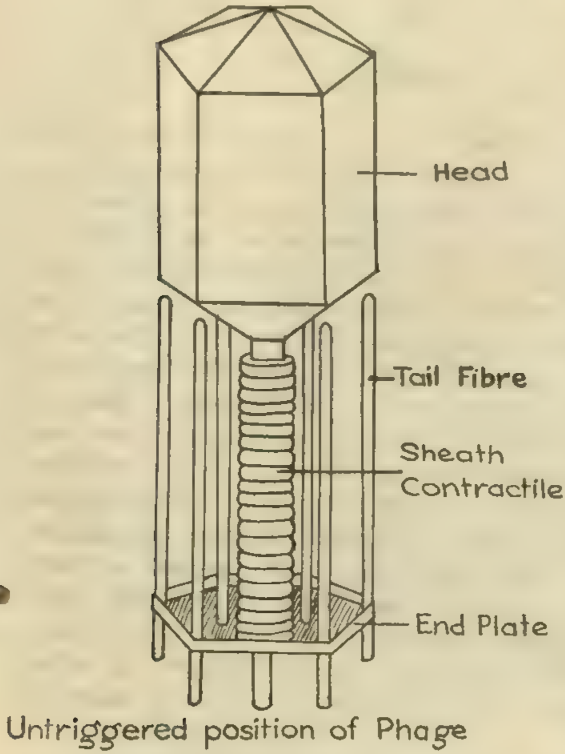


Fig. 1. Phage in untriggered position. In this state the tail fibres of the bacteriophage remain in a normal straight rod like position.

Bacteriophage, i.e. a virus which attacks bacteria has a tail and a head surrounded completely by a contractile protein sheath. The head of the phage is a bipyramidal hexagonal prism. The tail is a tube like structure surrounded by a helical sheath. An end plate carries six slender tail fibres and is situated near the end of the tail. (Figs. 1 & 2)

Classification—Viruses are classified variously depending on the shape, type of nucleic acid (DNA, RNA), type of host, anatomy, etc.

A. On the basis of their shape the viruses are divided into four types (Fig. 3), namely: (a) *Spherical form*—These viruses are spherical in shape (18-150 mμ), e.g., viruses of influenza, Japanese encephalitis, fowl sarcoma etc.

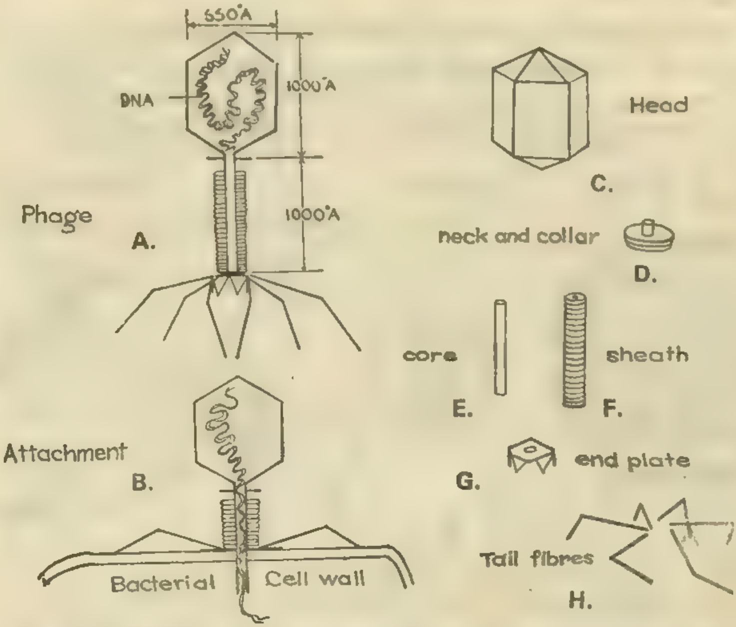


Fig. 2. Details of Bacteriophage structure: A—Dimensions of the phage, B—Phage during the period of adsorption and getting triggered, C—Only head portion of the phage, D—Only neck and collar region separated, E—Tail of the phage, F—Contractile sheath of the phage, G—End plate, H—Tail fibres separated from end plate.

(b) *Rod shaped form*—These viruses are rod shaped (350 mμ long and 15 mμ wide), e.g., viruses of tabacco mosaic disease and potato blight, etc.

(c) *Cuboidal form*—These viruses are cubical in shape (210-350 mμ), e.g., viruses of canary pox, vaccinia, etc. Vaccinia virus (222$\times$284 mμ) causes pox disease to cattle.

(d) *Spermatozoid form*—It is characteristic of bacterial viruses (bacteriophage). Such a virus possesses a head and a tail (47-104 mμ to 10-225 mμ), e.g. T_2 phage and lambda virus.

(e) Icosahedron form—It is a twenty-sided geometrical structure, e.g., TIV.

B. Viruses are divided into three groups depending on the *hosts* they infect. (a) *Plant viruses* cause diseases only of the

flowering plants. Some of the diseases of plants of economic importance caused by plant viruses are—(i) *Mosaic diseases* of tobacco, tomato, cabbage, cucumber, gourd, potato, etc., (ii) *leaf roll* of potato; (iii) *leaf curl* of cotton, and (iv) *chlorotic disease* of apple, jute, etc.

(b) *Animal viruses* infect animals. These viruses are again subdivided according to the tissues they infect: (i) *dermatropic viruses* infect skin and cause diseases like measles, chicken pox, etc.; (ii) *neurotropic viruses* infect nervous system and cause

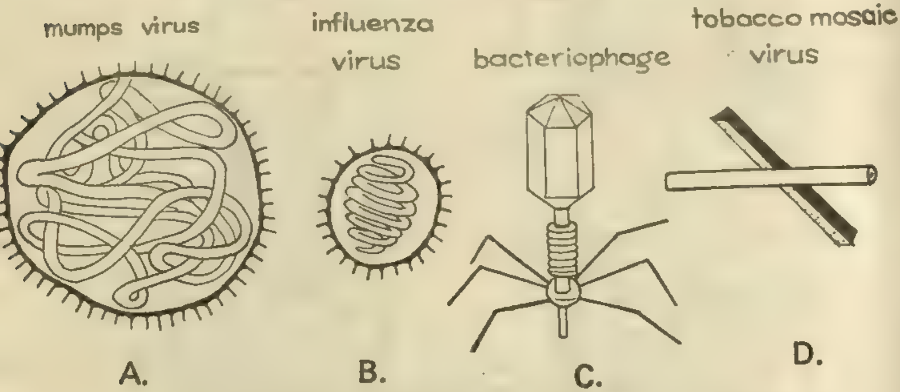


Fig. 3. Viruses with different shapes and sizes.

diseases like polyomyelitis, rabies, etc.; (iii) *Viscerotropic virus* infect the cells of the internal part of the body. Yellow fever and hepatitis are caused by such viruses: (iv) *pantropic viruses* affect several tissues. Some type of cancer and cancer like growth are caused by such viruses.

The only invertebrate animals in which virus diseases have been observed are the insects. Virus diseases have been found in fish, in amphibia and in birds. Among mammals they have been observed in man and most domestic animals.

Many of the animal viruses and most of the plant viruses are transmitted by arthropod vectors.

(c) *Bacterial viruses* or bacteriophages or phages are a group of viruses parasitic on bacterial organisms. They attack bacteria only and reproduce inside the bacterial cell.

C. Viruses may be divided into two groups according to the *nature of nucleic acid* they contain: (a) *Riboviruses*—In these viruses the core is made up of RNA. Various diseases caused by

them are influenza, measles, rabies, poliomyelitis, infectious hepatitis, dangue fever, yellow fever, etc.

(b) *Deoxyviruses* contain DNA. The diseases caused by these viruses are small pox, chicken pox, tumours, human herpes, etc.

More than 3000 viruses are known. These are grouped into five classes, eight orders and twenty one families.

Locomotion—Viruses have no means of locomotion.

Mode of infection of a bacteria by bacteriophage—It has been described earlier that the body of a bacteriophage consists of a head and tail, which is covered by a protein sheath. By the contraction of the protein sheath the tail end penetrates into the wall of bacterial cell resembling a minute hypodermic syringe and injects viral nucleic acid within the cell. When the tail fibres of a bacteriophage remain in a normal straight rod like position, it is called untriggered state or position (Fig. 1). But when a bacteriophage infects a bacterium it remains in a "triggered" position (Fig. 2B). In this condition the sheath contracts from the end of the tail and the tail fibres are released. At this position the viral surface make firm contact (adsorption) with the host cell membrane, (Fig. 4A) and react with it by releasing a penetrating enzyme which permits the viral DNA core to enter the cell at that spot. Thus at the triggered position viral nucleic acid is injected inside the host cell, (Fig. 4A). The injected viral chromosome, that is, nucleic acid travels towards the bacterial nucleus and either it dictates the host's entire metabolic machinery to devote in the formation of new viral particles or it becomes a provirus by incorporating itself into the DNA of bacterial chromosome.

Both protein and nucleic acid are responsible for the infecting power of a virus, a virus which lacks the protein coat cannot infect any organism.

Reproduction—Viral reproduction is intracellular, i.e., they can reproduce only when they enter within a living cell. They are obligate parasites; all attempts to cultivate them outside living hosts have failed. They possess no source of power and thus cannot grow on their own, but all the information needed for their reproduction are embodied in their nucleic acid.

Within a few minutes after its entry, the viral chromosome multiplies inside the host cell forming a number of generations of viral chromosomes (eclipse period Fig. 4B). Simultaneously the host cytoplasm becomes engaged in the manufacture of protein

envelopes, which soon surround individual viral chromosomes. As many viruses are formed within the host cell, the membrane of the host cell dissolves and the viral particles (200-300 approximately)

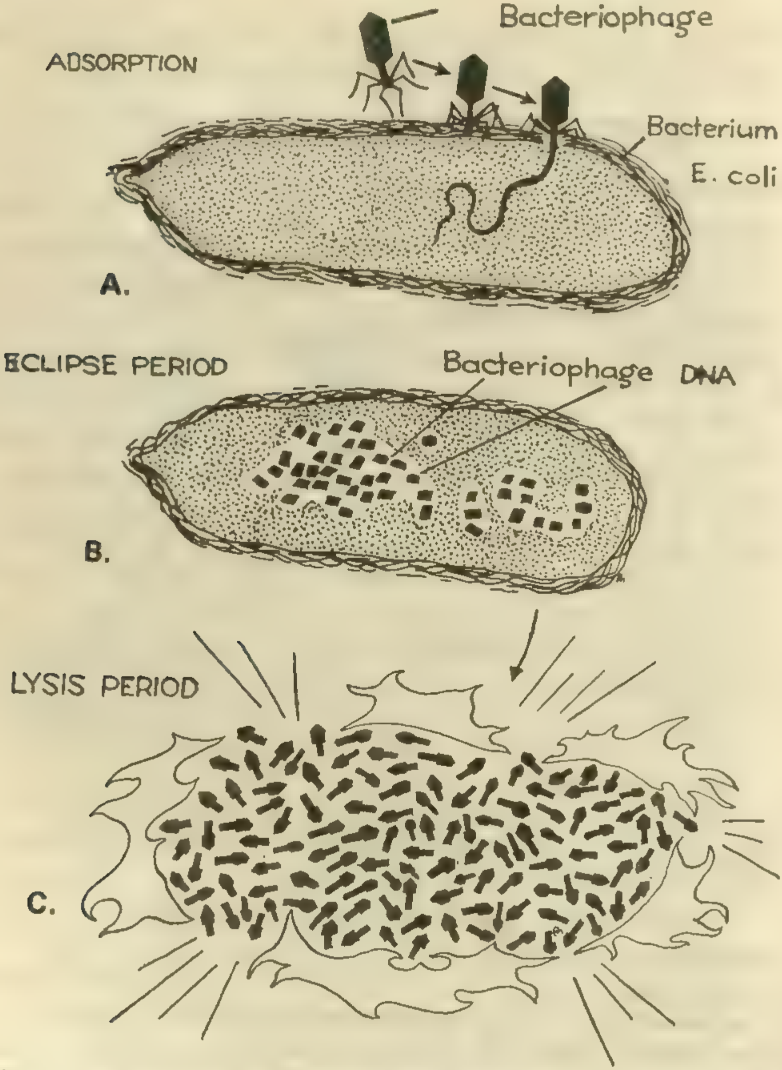


Fig. 4. Reproduction of Bacteriophage. A—Phage before getting adsorbed to the surface of bacterium. During the triggered position when phage gets attached to the bacterial surface and releases its nucleic acid into the bacterial cell. B—Eclipse period when the phage nucleic acid multiples in the host cell. C—Lysis period when the bacterium bursts to release the reconstructed phage particles.

emerge. Thus the bacterial cell undergoes lysis (break down) due to multiplication of the virus within it (Fig. 4C).

But in certain cases the bacteriophage may exist within the bacterial cell without doing any harm to it. In such case the viral nucleic acid remains associated with bacterial chromosome and divides along with the division of the bacterial chromosome. This inactive or passive form of virus is known as *prophage* or *probacteriophage*. The viral nucleic acid acts as a new gene in the bacterial chromosome. The bacteriophages are harmless as long as the environmental conditions remain unchanged. But during unfavourable environmental conditions the prophage causes bacterial lysis (break down). Those bacteria which carry prophage are known as *lysogenic bacteria*. Bacteriophages that can form prophage are known as *temperate phages* in contrast to the *virulent phages*, which always cause destruction of bacterial cell on infection. Bacteria carrying prophage, develop immunity to attack of same phage type.

Bacteriophages that have attacked and caused lysis of the bacterial cells may transfer parts of bacterial chromosomes from these cells and inoculate these parts to other bacteria, thereby causing genetic change of the bacterial chromosomes. This process is known as *transduction*. Thus bacteriophages are responsible for genetic recombination in bacteria where sexual reproduction is not a regular phenomenon.

Origin of Virus—Virus may represent the primordial form of life which appeared on the earth, because they have never been seen to multiply outside the cells of other organisms. At one particular stage of the earth the macromolecules of the kind of virus would have had the power of autoduplication in presence of substances with low molecular weight and proper energetic conditions inside certain system. Then successively these primitive environmental conditions have changed and the macromolecules would have found only the possibility to have a parasitic life and would have utilized ready-made fragments produced by the metabolism of the host. These macromolecules essentially would have utilized the energy produced by the process of disintegration which are continuously in progress in every cell.

2

BACTERIA

Bacteria are extremely minute and most abundant group of organisms in the world. They are the most primitive forms of life and their fossil records have been found in rocks which are some 3.2 billions years old. They are usually about 1 μ in diameter but ranges from 0.1 μ—10 μ in length.

The bacteria are present practically everywhere, in soil, in water, in the atmosphere and in the digestive tracts of animals. They are also found in extreme environments, such as, icy conditions of Antartica to boiling waters of hot springs, where no other life forms can exist.

Some of them lead a parasitic mode of life attacking the living cells of plants and animals and deriving their nutrients from them, while others grow on the dead and decomposed plant and animal products and are, therefore, saprophytic. The saprophytic bacteria are beneficial because by their action the materials once incorporated into the bodies of living organisms are made available to successive generations. Many of the parasitic bacteria produce pathological or disease conditions in plants and animals and are said to be pathogenic. Most of the infectious diseases of man and other animals, viz., cholera, typhoid, tuberculosis, diphtheria, tetanus, etc. are brought about by the activities of different kinds of pathogenic bacteria.

Some bacteria live only in absence of oyxgen (obligate anaerobes) while others can live both in presence or absence of oxygen (facultative anaerobes).

Structure—Bacteria are usually unicellular but the cells of some bacteria may be branched and in some cases the cells remain united together to form filaments. The bacterial cells are extremely small. *These cells are procaryotic* (*Fig.* 5) *and thus less complex than those of most organisms* (*eucaryotic cell*). Each cell has a definite cell wall which contains no cellulose, but is composed of nitrogenous compounds and carbohydrate. Inside the cell wall there is a cell membrane. The cell membrane is very thin and is made up of lipid and protein. The cell membrane usually has many folds which are known as mesosomes. Some bacteria

have a thin gelatinous sheath, called the *slime layer* surrounding the cell wall. The cells contain granular protoplasm and there is no definite organised nucleus. Chromatin granules (DNA) occur within the protoplasm and represent the nuclear material (nuclear substance) of the cell. Ribosomes, granules of reserve

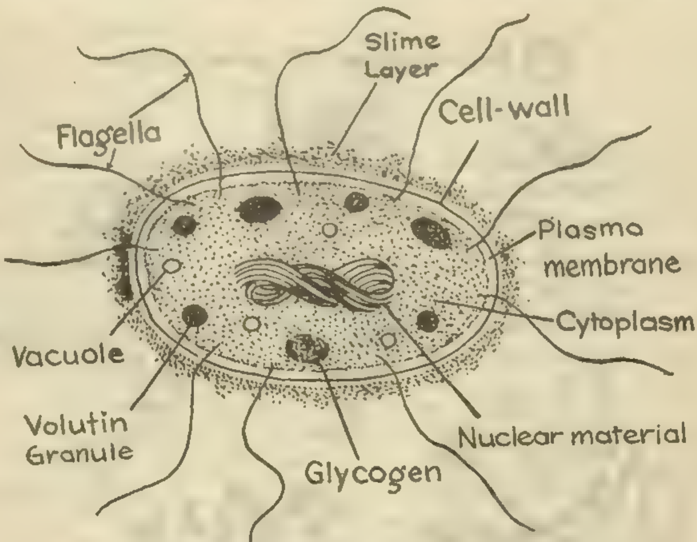


Fig. 5. Structure of a typical bacterial cell.

food (glycogen and volutin granules) and small vacuoles are present in the cytoplasm. Bacterial cells lack mitochondria, although mesosomes are compared with mitochondria by many scientists. Some forms of bacteria contain red or purple colouring compounds.

In some species the gelatinous sheath of the cell walls swell greatly and the cells or the filaments of bacteria are grouped together in large masses in mucilage and form a sort of scum (*zooglea stage*).

Some kinds of bacteria have flagella; by means of which they can swim. Besides flagella some bacteria have pili. Flagella are long, slender, wavy structures and are the protoplasmic processes of the cell. Flagella are made up of flagellin, a type of protein. Non-flagellated bacteria are known as *atrichous*. The flagellated bacteria are classified into four types according to their type of flagellation: (a) *monotrichous*—a single flagellum is present at

one end of the cell; (b) *lophotrichous*—having a tuft of flagella at one end; (c) *amphitrichous*—having a tuft of flagella at both ends; and (d) *peritrichous*—having flagella on the entire surface of the cell. Short hair like structure called pili may be present over the surface of the bacterial cell. Pili are shorter than flagella and are formed from the cytoplasmic membrane.

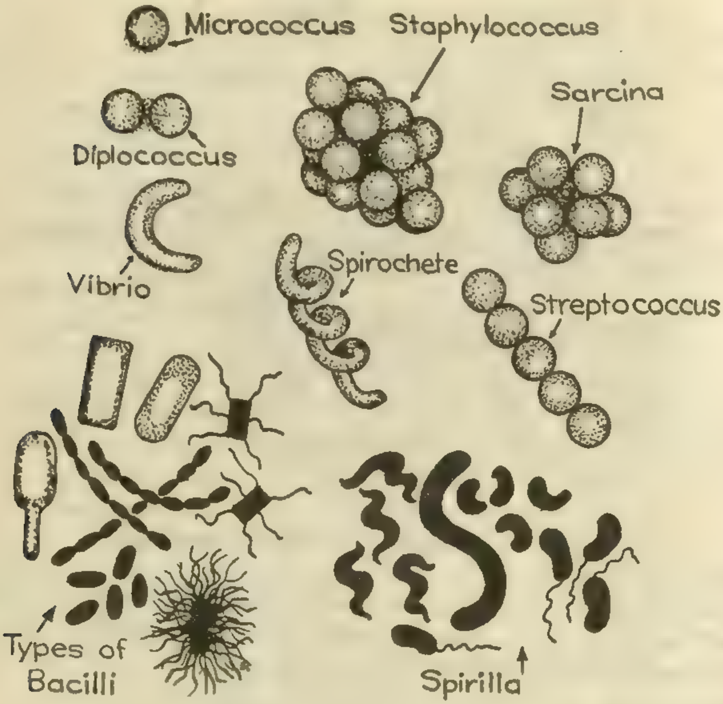


Fig. 6. Types of bacteria.

Types of bacteria (Fig. 6)—The cells of bacteria vary greatly in shape and are usually distinguished by their shape. There are three principal forms of bacteria, namely, cocci, bacilli and spirilla.

(a) *Cocci* (sing. *Coccus*)—These bacteria are spherical in shape. A spherical one-celled coccus is called *micrococcus*, when two cocci remain together then they are said to be *diplococci*. Sometimes a chain of cocci is found. These are known as *streptococci*. Clusters of spherical bacteria are called *staphylococci*. Pneumonia is caused by diplococcus and staphylococcus causes many serious infections.

(b) *Bacilli* (sing. *Bacillus*)—These bacteria are rod shaped. Curved rod shaped bacteria are called *vibrios*. They may be with or without flagella.

(c) *Spirilla* (sing. *Spirillum*)—Long, usually spirally coiled bacteria are called *spirilla*.

Spirochetes—They are unicellular bacteria with spirally curved cells. They can be distinguished from other bacteria by flexibility of their cells and by the absence of a rigid cell wall.

Nutrition—According to their modes of nutrition bacteria may be autotrophic or heterotrophic. Autotrophic bacteria are photosynthetic or chemosynthetic. The photosynthetic bacteria (*e.g. Chlorobium limicola*), which contains photosynthetic pigment, synthesizes food in presence of light from carbon dioxide and inorganic compounds. They get energy from sunlight. The chemosynthetic bacteria (e.g. *Thiobacillus dinitrificans*) obtain energy

$$\underset{\text{Hydrogen sulphide}}{2H_2S} + CO_2 \xrightarrow{\text{Sunlight}} \underset{\text{carbohydrate}}{CH_2O} + 2S + H_2O$$

for food synthesis from the oxidation of inorganic compounds. The energy released is used to convert CO_2 through several reactions to carbohydrate.

$$\underset{\text{Sulpher}}{5S} + \underset{\text{Potassium nitrate}}{6\,KNO_3} + 2\,H_2O \rightarrow \underset{\text{Potassium Acid sulphate}}{4\,KHSO_4} + \underset{\text{Nitrogen}}{3\,N_2} + \underset{\text{Potassium sulphate}}{K_2SO_4} + \text{Energy}$$

Heterotrophic bacteria may be parasitic or saprophytic. They secrete enzymes into the surrounding media on which they live to get food in simple diffusible form for their nutrition.

Reproduction: Bacteria usually reproduce vegetatively or asexually. Sexual reproduction is rare.

Vegetative reproduction (Fig. 7)—Bacteria usually reproduce vegetatively by simple *fission* and from this the phylum name

Schizophyta (meaning 'fission plants') has been derived. The cell increases in size, the cytoplasmic membrane and cell wall grow inward around the middle of the cell. This constriction increases and ultimately two daughter cells are formed which later separate. Is some bacteria the cells multiply with such rapidity that the rate of increase is astonishing. When the cell wall divides incompletely then chains of bacteria are found. During bacterial cell division the daughter DNA molecules are regularly attached to the cytoplasmic membrane at specific positions of the mother cell which later become daughter cells.

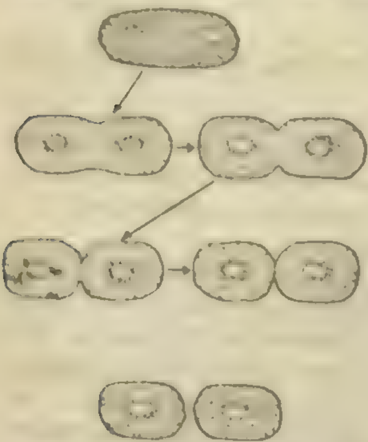


Fig. 7 Fission of bacterial cell.

Asexual Reproduction (Fig. 8)—Some bacteria (the bacilli) form thick-walled dry spores, which are always resting spores. The protoplasmic content of a cell round itself off and clothes itself with a thick membrane, forming only one spore (*endospore*). This process may not be regarded as a method of reproduction, since one spore changes into one vegetative cell only. The spores can resist draught, extreme heat and cold and so they are regarded as resting stages of the organisms to tide over unfavourable conditions.

Fig. 8 Sporulation of bacteria. Endospore formation in two types of bacteria: X, *Clostridium*, Y, *Bacillus*.

Sexual Reproduction—In 1947 Lederberg and Tatum working with intestinal bacteria *Eschericia coli* observed a sort of conjugation. During this process a part of the bacterial chromosome is transferred into the other. The new bacterium so produced can live under conditions, in which both the parents can not live.

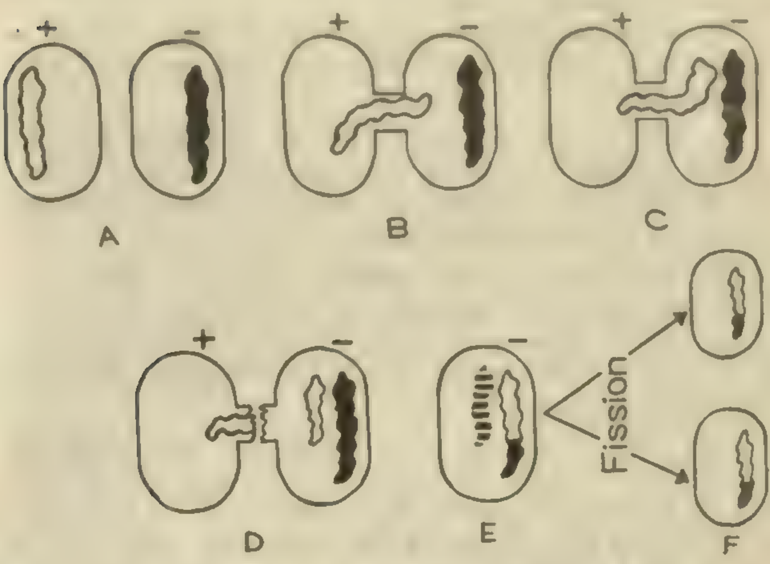


Fig. 9. Diagram showing stages of bacterial conjugation.

During sexual reproduction some bacteria act as donor and others as recipient. The donor and recipient bacteria by some means come near and contact each other. At the region of contact cell walls dissolve and form a hollow pilus which acts as a conjugation bridge ; through this the chromosome of the donor enters into the recipient. Usually before the complete entry of the donor chromosome the conjugation breaks. As a result the recipient bacterium getting only portion of the chromosome of the donor bacterium forms an incomplete zygote called *Merozygote* (Jacob and Wollman, 1961). Later there is a crossing over and recombination of the chromosomes of the recipient and the donor forming the newly arranged chromosome of the bacteria. The portion of the recipient chromosome not uniting gradually disorganizes. At the time of binary fission the daughter bacteria bear the character of both the donor and recipient bacteria. (Fig. 9).

Economic significance of bacteria—Bacteria are popularly looked upon as agents causing diseases in plants and animals and as such they are usually condemned as enemies of mankind. They are no doubt responsible for bringing about diseases, but their beneficial effects are also very great.

Benificial Activities of bacteria

Agents in soil fertility—Bacteria play an important part in maintaining the fertility of agricultural soils. This they do in three different ways.

(i) *Decay and ammonification*—By producing profound chemical changes some bacteria decompose dead leaves, branches, etc. and change the protoplasm and stored proteins into ammonia. The process is called ammonification.

(ii) *Nitrification*—Other bacteria, millions of which, live in the soil, convert the ammonia into nitrates, just the form of nitrogen that is absorbed in greatest quantities by higher plants. By the process of nitrification ammonium compounds cannot be accumulated in the soil.

(iii) *Nitrogen fixation*—It is known that most plants get their supply of nitrogen in the form of nitrates from the soil, Nitrogen as a gas is abundantly present in the atmosphere, but few plants can absorb the free nitrogen of the atmosphere. One form of bacteria called *Azotobacter* is able to take free nitrogen from the air and uses it in the manufacture of nitrogenous compounds. This process is known as nitrogen fixation. Through the death of these organisms fertility of the soil is increased by the addition of nitrogen present in them.

Rhizobium, an interesting genus of bacteria, fixes atmospheric nitrogen in co-operation with plants belonging to the Pea family. The bacteria which live in the soil, attack the roots of these plants. They live there and form swellings called nodules or tubercles. Within these nodules the micro-organisms fix atmospheric free nitrogen. From this nitrogen nitrogenous compounds are built up, some of which are used by the bacteria and others by the host plant.

Bacteria for better health

Vitamin B_{12} (cobalt vitamin) is used extensively for preventing the blood disease pernicious anaemia of human beings. Vitamin B_{12} is usually obtained from beef liver. The recovery of large

amounts of vitamin B_{12} from beef liver is a difficult and costly job. From investigations it has been proved that a number of bacterical species synthesise B_{12} far in excess of their own needs. It has now been possible to obtain the excess vitamin B_{12} from huge cultures of those bacteria. This discovery is an excellent example of one of the many ways by which bacteria can be utilised for human benefits.

Bacteria always dwell in large numbers in the human system usually in the intestines. These bacteria are important in completing certain digestive processes. They are so important that without them digestion of food is incomplete.

Bacteria and antibiotics—Antibiotics or the 'wonder drugs' are a group of organic substances, which have been synthesised by one kind of organisms and inhibit or destroy other kinds of organisms. These antibiotics are found to check various diseases of animals including human beings. Valuable antibiotic drugs have been obtained from various bacteria. The bacteria belonging to the sub-group, *Actinomycetes* produce a number of important antibiotics, such as, streptomycin, terramycin, aureomycin, etc. Other antibiotics produced by bacteria are subtilin, polymyxin, tyrothricin, bacitracin, etc.

Bacteria in dairy industry—Bacteria are used to a great extent in dairy industry. The manufacture of butter and cheese depends on bacterial fermentation. Some bacteria rapidly change milk sugar into lactic acid, and thus sour the milk and cause the coagulation of the protein (caesin) which is popularly called curdling. The lactic acid bacteria are useful in butter making, because the yield of butter is increased and the flavour is improved by the presence of lactic acid.

Bacteria in other industrial uses—Bacteria are utilized for curing and ripening of tobacco leaves, for fermentation of tea leaves in the preparation of tea, fermentation of vinegar from alcohal (by acetic acid bacteria), fermentation of sugar into alcohol (in addition to yeast, a fungus), conversion of hide into leather during the process of tanning.

Retting of fibres—The extraction of fibres like jute, hemp, etc. involves a stage called retting. During the process, the stems of plants are kept under water for a few days when by the action of certain bacteria the fibrous portions are loosened from the woody regions. After retting the fibres can be easily extracted from the stem.

Harmful activities of bacteria—Many bacteria, infact living plants and animals, and are responsible for causing various and often serious diseases in them, sometimes in epidemic form. Bacteria infect human beings and animals through their food, water and milk. After infection of the body they produce a toxin (poison) which causes many of the serious diseases of human beings and domestic animals. Some such diseases caused by bacteria are typhoid fever, tetanus, diphtheria, tuberculosis, leprosy, pneumonia, dysentry, cholera, etc. Bacteria also attack plants and cause various diseases, such as, ring disease of potato, black-rot of cabbage, canker of citrus, bacterial rot disease of rice, blight of apple, etc.

Various types of bacteria are responsible for the decay of vegetables, fruits, meat, cooked food, etc. particularly during summer months.

3

ALGAE

Algae are found in the fresh water of ponds, ditches, pools, rivers and swamps and also in the salt water of the oceans. There are some free floating algae which together with similar animals form the plankton of tanks, lakes and also of the oceans. A number of algae often grow on other plants as epiphytes. Some algae live with other organisms in symbiosis, that is, an association of two organisms to their mutual advantage, as for example, some algae live with fungi forming what are know as the *lichens*. The algae supply food to the fungi and the fungi provide water and some amount of mechanical protection to the algae.

Most algae have no economic importance. Some, however constitute the chief source of food for fish and other aquatic animals. Many marine algae are important source of iodine, potash and other minerals. Some blue green algae are known to fix atmospheric nitrogen in the soils and are therefore useful in increasing the nitrogen content of the soil. During the present time several species of green algae are now being cultured extensively for human consumption. About 25 to 30 species of the giant Phaeophyceae or brown algae are taken by the Japanese as food. People of various other parts of the world, specially in the Far East, eat several species of red algae also. One of the red algae, *Porphyra*, which is eaten by many of the inhabitants of the North Pacific Basin, has been cultivated in Japan and China for many centuries. The cultivation of *Porphyra* has become an industry in Japan where more than 0.5 million persons are employed at present for its cultivation. Sea weeds (algae growing in sea are so called) are generally not of high nutritive value, as human beings do not have necessary enzymes to break down the sea weed carbohydrates. These weeds however, provide necessary salts as well as number of important vitamins and trace elements and so are valuable supplementary food.

One of the most useful commercial applications of any algae is the preparation of agar which is made from miscellaneous materials extracted from the cell walls of a number of genera of

red algae. Agar is used to make the capsules that hold vitamins and other drugs, as a base for cosmetic and also for other purposes. It is also an important culture medium for bacteria and other micro-organisms. It can be used for various other preparations. Agar is produced in many parts of the world but Japan is the principal centre of production.

The algae are grouped into several classes, based mainly upon their characteristic differences in colour although the colour differences are not the most important ones. The main classes are : (i) *Myxophyceae* or blue-green algae, e.g., *Oscillatoria*; (ii) *Cholorophyceae* or green algae, e.g., *Ulothrix*, *Spirogyra*, *Oedogonium*, etc. ; (iii) *Phaeophyceae* or brown *algae* ; and (iv) *Rhodophyceae* or red algae.

OSCILLATORIA

Oscillatoria [Fig. 10] is one of the commonest forms of blue-green algae. It is most cmmonly found in bluish black little patches on wet soil. It may be also found in shallow pools of water.

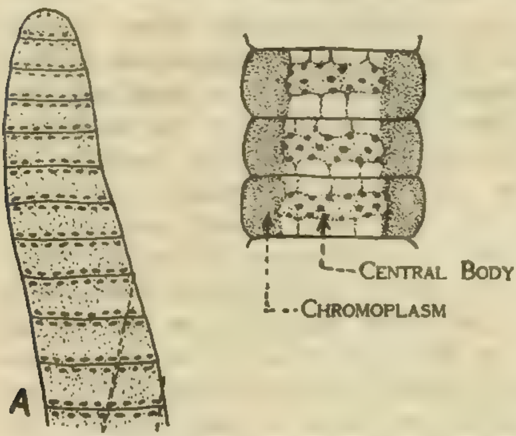


Fig. 10. A part of the *Oscillatoria* filament. Enlarged view of three cells to show the different parts.

Structure — The alga consists of a simple unbranched row or filament of cells. The elongated filaments exhibit a kind of movement the mechanism of which is not well understood. They sway and oscillate backward and forward and sometimes move longitudinally a short distance. This kind of oscillating movement has suggested the name of the plant.

The filaments of *Oscillatoria* are usually found in tangled masses. The cells of the filament except the apical cell are disc-shaped or cylindrical and may be shorter than they are wide. The apical cell is hemispherical or conical in shape. Each cell is surrounded by a very thin cell wall consisting of cellulose and pectic

substance. The protoplasm is differentiated into an outer coloured (*chromoplasm*) and an inner colourless region (*centroplasm or the central body*) [Fig. 10]. There are no definite plastids ; the colour of the cells is due to the presence of a blue pigment in addition to chlorophyll and the accompanying yellow pigment which are all diffused throughout the protoplasm. There are no vacuoles, but numerous granules, are present in the cell ; most of them are composed of *glycogen*, a carbohydrate, similar to starch. The cell does not contain a true nucleus. The central body consists of a relatively dense mass of material, and it contains some granules of chromatin. The central body may, therefore, be described as a primitive nucleus, but without a nucleolus and a nuclear membrane.

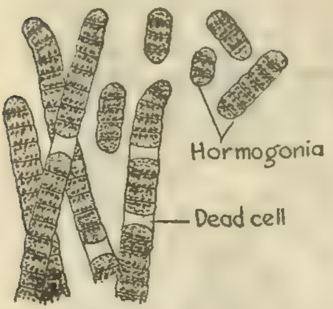


Fig. 11. *Oscillotoria* filaments showing hormogonia.

The number of cells of a filament is increased by cell division. The cells divide by a process of constriction taking place in parallel planes.

Reproduction—In *Oscillatoria* sexual and asexual methods of reproduction are unknown. Reproduction takes place vegetatively by the accidental breaking of the filaments into pieces of varying lengths. Through the occasional death of a cell or a group of cells 'separation discs' are formed here and there. At these regions the filament of *Oscillatoria* may break into segments called *hormogonia*. Each hormogonium by active cell division gives rise to a new plant (Fig. 11).

CHLAMYDOMONAS

Chlamydomonas is a unicellular green alga belonging to the family Chlamydomonaceae. It is widely distributed and is found in ponds, ditches and other stagnant water or in damp soils.

Vegetative body—[Fig. 12A] The body is spherical, oval, elliptical or pear shaped and composed of only one cell (unicellular). The cell is surrounded by a thin wall of cellulose, which is sometimes enclosed by a gelatinous sheath. At the anterior end of the cell there are two flagella [Fig. 12A]. Usually two contractile vacuoles are found at the base of the flagella at the anterior end. These contractile vacuoles undergo rhythmic contraction and ex-

pansion and may have respiratory or excretory function. There is an orange or red pigment spot on one side near the anterior end. This spot is known as *eye spot* and it is light sensitive. The eye spot is supposed to direct the movement of the flagella. In the posterior

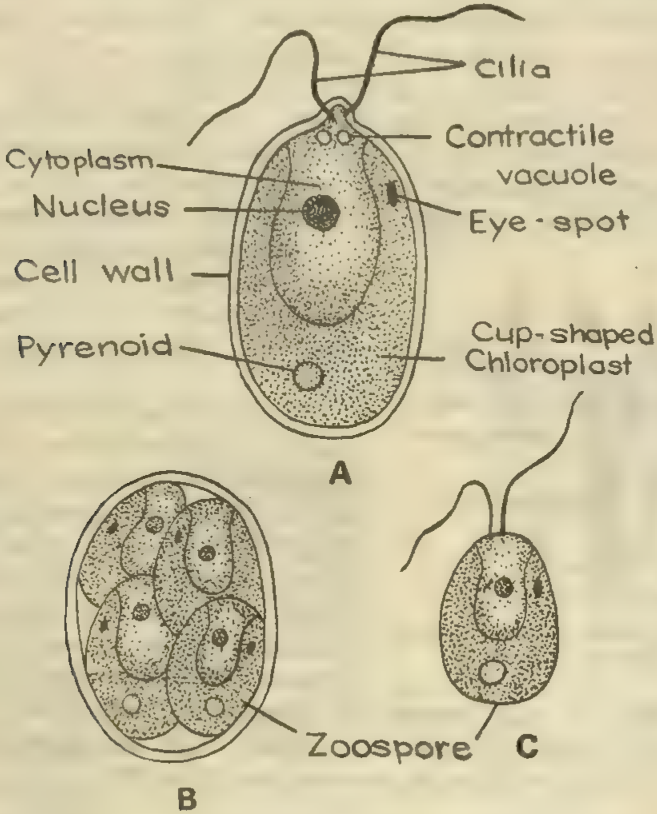


Fig. 12. *Chlamydomonas* : A—Vegetative cell showing its structure, B—formation of zoospores, C—a zoospore.

region of the cell there is usually a single large cup shaped chloroplast, which contains usually one (sometimes 2 or more) pyrenoid. The pyrenoid has a central protein part surrounded by many starch grains. In certain cases the chloroplast is star shaped or laminated. There is a single nucleus, which is more or less centrally situated in the colourless cytoplasm.

Reproduction

Chlamydomonas reproduces asexually and sexually.

Asexual reproduction—[Fig. 12B, C] Asexual reproduction takes place by means of zoospores. During the formation of zoospores the flagella are withdrawn and the protoplast assumes a round shape. The protoplast divides and redivides forming 2, 4 or 8 daughter protoplasts. Each daughter protoplast is then surrounded by a wall and develops two flagella at the anterior end. The zoospores are liberated by the gelatinisation or rupture of the mother cell.

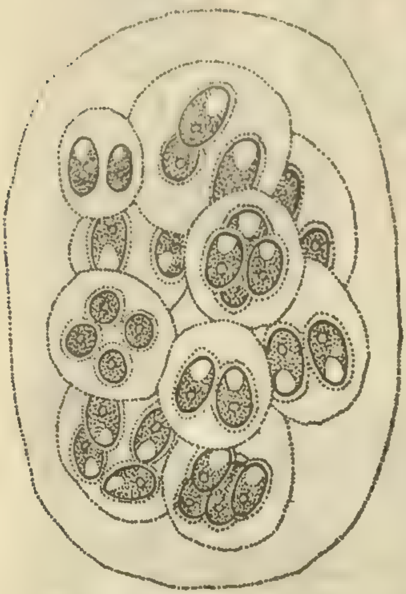


Fig. 13. Palmella stage of *Chlamydomonas*.

Palmella stage—The daughter protoplasts formed by successive divisions in *Chlamydomonas* growing on damp soil do not develop flagella. The cell wall of the mother cell undergoes gelatinisation and surrounds these daughter cells. The protoplasts of these daughter cells divide and redivide forming many cells which are surrounded by the gelatinous matrix formed by the gelatinisation of the daughter cell walls. Thus hundreds of cells are found surrounded by a common gelatinous matrix forming colonies. This is known as palmella stage, [Fig. 13] as it resembles *Palmella*, a green alga. When this palmella stage is flooded with water then each daughter cell develops a pair of flagella forming a new plant and swims out of the colony.

Sexual reproduction—[Fig. 14A-G] Sexual reproduction in *Chlamydomonas* takes place when conditions are unfavourable. The individual plants become round and their contents divide. The gametes are like zoospores but they are much smaller and more numerous than zoospores. During gamete formation the protoplast divide and redivide forming 8, 16, 32, 64 or more daughter protoplasts, each of which then develops two flagella and is ultimately transformed into a gamete. They are usually naked, but sometimes possess wall. Usually the male and female gametes are exactly alike

and are thus called isogametes. The gametes are liberated by the rupture of the mother cell wall. Usually gametes produced by different cells (heterothallic) unite forming the zygote (zygospore). But in certain cases gametes produced by same cell unite (homothallic). Sexual reproduction taking place by the union of similar gametes

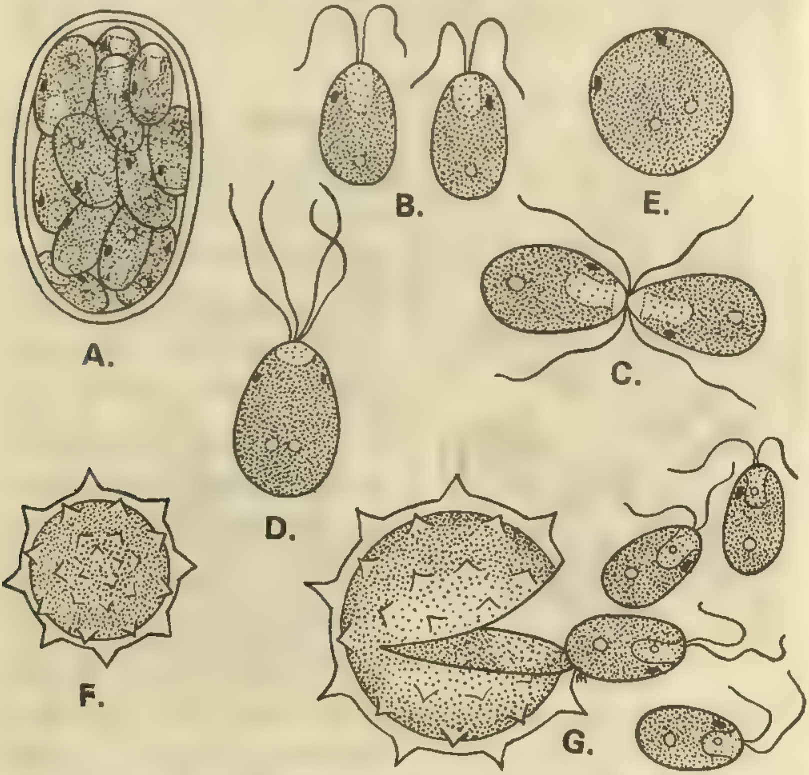


Fig. 14. Sexual reproduction in *Chlamydomonas*. A—Cell that produces many gametes ; B—two similar gametes ; C—the gametes uniting ; D—zygote with four flagella ; E—young zygote ; F—zygote with thick wall ; G—four zoospores escaping from the zygote wall.

is known as isogamy and the zygote produced by isogamous reproduction as *zygospore*. In certain cases the uniting gametes of *Chlamydomonas* are not similar, one of them is larger than the other, but both have flagella. Such gametes are called anisogametes and the type of reproduction as anisogamy. The zygote formed as a result of union of dissimilar gametes is called *oospore*. During fusion of two gametes the flagellate ends unite first forming a quadriflagellate zygote, which may swim for sometime. Soon the flagella are withdrawn and the zygospore is surrounded by a thick

wall. After a resting period the zygote germinates. During germination the diploid nucleus of the zygote divides by meiosis forming four haploid nuclei, three of which may degenerate. The uninucleate protoplast of the zygospore then divides forming 2 or 4 daughter cells, each having two flagella. These cells grow and are then liberated by the rupture of the zygote wall and become individual *Chlamydomonas* plants.

SPIROGYRA

Fig. 15

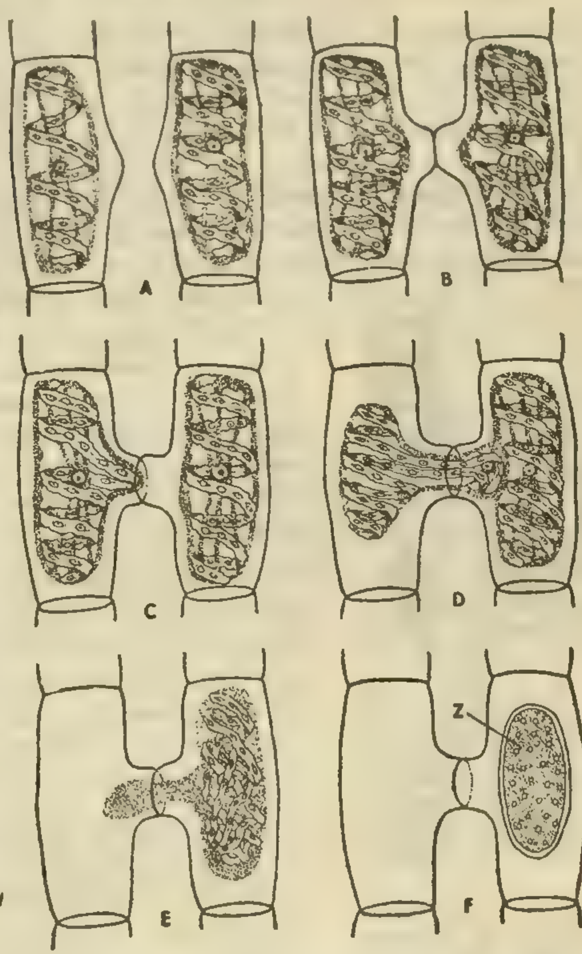


Fig. 16

Fig. 15. Structure of a vegetative filament of *Spirogyra*. CH. ribbon-like chloroplast ; Py, pyrenoid ; Cy, cytoplasm ; N, nucleus ; CW, cell wall

Fig. 16. Sexual reproduction of *Spirogyra*. A-F, Different stages of scalariform conjugation and formation of the zygote ; Z, zygospore.

Spirogyra is one of the commonest filamentous green algae. The filaments are always unattached and float freely in tangled masses in stagnant fresh water. Their outer walls are mucilaginous and on account of this the filaments are slimy to touch. *Spirogyra* can be easily distinguished in the field without the aid of a microscope from any other alga by its unattached condition and by the very slippery feeling of the masses of filaments.

Structure—Each plant consists or an unbranched filament which does not show any distinction of base and apex. The filaments consist of a row of elongated cylindrical cells, each of which is surrounded by a cell wall. Each cell has a layer of colourless cytoplasm along the wall surrounding a central vacuole. The nucleus is generally in the centre of the cell where it is surrounded by a layer of cytoplasm, strands of which run through the vacuolar space and join the peripheral cytoplasm on all sides [Fig. 15]. The most characteristic feature of *Spirogyra* is the spiral ribbon-like chloroplast, which gives the plant (genus) its name. One or more of these chloroplasts lie embedded in the peripheral cytoplasm. [Two are shown in Fig. 15]. Each chloroplast contains several *pyrenoids* which are highly refractive nodule-like protein bodies surrounded by coatings of starch.

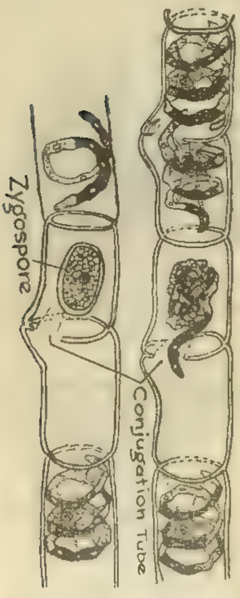


Fig. 17. Sexual reproduction of *Spirogyra*. Various stages of lateral conjugation.

Reproduction—There is no special method of asexual reproduction. When the filaments are accidentally broken into pieces consisting of one or more cells, each of these pieces by ordinary cell division may grow into a new filament (vegetative reproduction).

Sexual reproduction [Figs. 16A-F & 17]—Sexual reproduction in *Spirogyra* is effected by conjugation. In this process two filaments chance to lie close together and more or less parallelly. The entire protoplasmic contents of an ordinary vegetive cell form a *gamete*. From the middle of each cell a short lateral outgrowth (conjugating tube) grows out towards the other

filament. These outgrowths from two cells lying opposite each other, join at their ends and elongate, pushing the filaments apart. Ultimately the end walls of the outgrowths fuse. By the dissolution of the end walls of the tubes a continuous passage is formed from one cell to another. Meanwhile the protoplasm of each conjugating cell (*gametangium*) contracts somewhat to form the gamete. Then the gamete of one cell passes over through the tube to the corresponding cell of the other filament containing another gamete and the two gametes fuse (Fig. 16D-E). Thus all the gametes of one filament flow through the tubes to the cells containing the gametes of the adjacent filament leaving empty cell walls behind. This is called *scalariform conjugation.*

In a few species of *Spirogyra*, conjugation takes place between adjacent cells of the same filament. In this process a passage is formed by a conjugation tube developed near the adjoining ends of the conjugating cells. This method of conjugation is known as *lateral conjugation* [Fig. 17].

Fig. 18. *Spirogyra* — germination of the zygospore.

With the fusion of the gametes a *zygospore* (or *zygote*) * is formed. The zygospore is ellipsoidal or spherical in shape and is provided with a thick wall. The zygospore rests for some time, generally over a period of unfavourable growth, and on the return of favourable conditions it germinates and produces a new filament [Fig. 18].

A gamete which fails to unite with another gamete may become directly converted into a thick-walled spore. Such spores are called *azygospores*, which, just as do zygospores, give rise to new filaments on germination. This type of reproduction is known as parthenogenesis.

* The product of the union of two equal sized gametes which can not be distinguished as male and female, is called *zygospore*. The product of union of a male gamete (usually small in size) with a female gamete (usually large in size) is called an *oospore*. *Zygote* is a common term applied to both zygospore and oospore.

In *Spirogyra* the gametes are structurally alike and cannot be distinguished as male and female (isogametes); but the gametes of one filament are active, while those of the other are passive and receptive. This fact suggests that although the gametes are structurally similar, physiologically they may be regarded as male (the active gametes) and female (the passive and receptive gametes).

It is to be noted that the zygote is formed as a result of fusion of two gametes each of which has n chromosomes; so the nucleus of the zygote will have $2n$ chromosomes. The nucleus of the zygote undergoes reduction division (meiosis), the resulting 4 nuclei will each have n chromosomes. Three of these nuclei disorganise and only one nucleus with n chromosomes is to be found in the zygote.

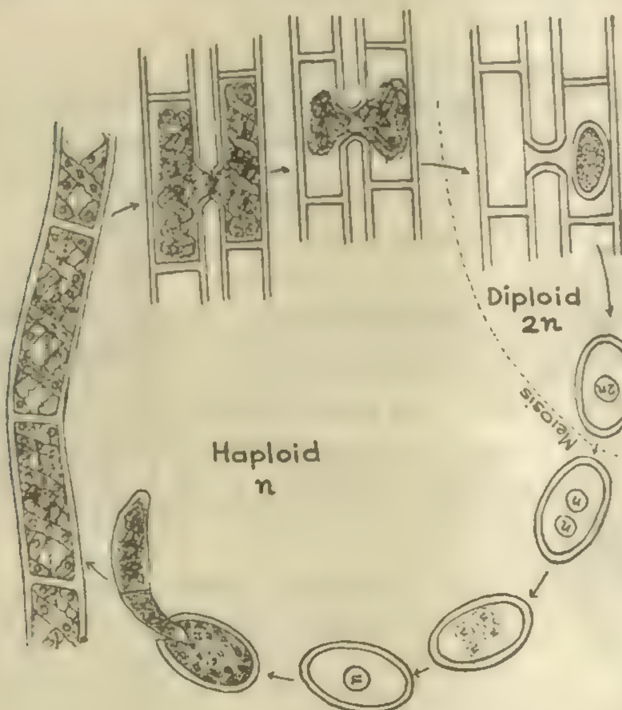


Fig. 19. Life cycle of *Spirogyra*.

The life cycle of *Spyrogyra* plant is shown in figure 19.

4

FUNGI

Fungi form a very large group of plants which contain no chlorophyll and so they must live either as saprophytes or as parasites. The saprophytic fungi grow in a variety of conditions on dead or decaying organisms. Parasitic fungi, on the other hand, grow on living plants and animals including human beings. They have remarkable power of disintegrating or dissolving almost anything they attack by the secretion of suitable enzymes. Parasites pass their entire life on living hosts, plants or animals. The body of the fungi except the unicellular forms is usually made up of an interwoven mass of very fine and delicate thread-like structure called *hyphae* (sing. *hypha*) which are collectively known as *mycelium*. The walls of the hyphae are usually made of a substance called *chitin*.

Fungi are classified into the following groups—(i) *Myxomycetes* or slime fungi; (ii) *Phycomycetes* or algal fungi having aseptate mycelium e.g., *Mucor*, etc; (iii) *Ascomycetes* or ascus fungi, e.g., Yeast, *Penicillium*, etc; (iv) *Basidiomycetes* or basidium fungi, e.g., *Agaricus* and (v) *Fungi imperfecti* or Deuteromycetes—mycelium septate, sexual reproduction not known, e.g., *Colletotrichum*, *Helminthosporium*.

Economic significance of fungi

Fungi are responsible for causing various diseases of plants and animals. The indications of diseased conditions in plants (and also in animals) are seen as abnormal symptoms or outward signs which appear on the different parts of plants (leaves stems and roots etc.). In the 19th century methods were developed which made it possible to grow the fungi separately in suitable nutrient media and since then the detailed study of the pathogenic fungi has become possible. Pathologists have thus been able to study some of the interesting problems relating to the life history of such fungi. From these studies methods of controlling the diseases caused by such fungi in plants and animals have been evolved.

Many parasitic fungi attack several field crops, cultivated plants, ornamental and useful plants and also many wild plants and cause serious diseases in them. The fungi damage the host plants by obtaining food from them, blocking the conducting tissues, and by destroying the affected cells and cause their ultimate destruction. A particular disease may spread from field to field by the spores of the disease causing fungi which may be seed borne, wind borne or insect borne, and as a result there is huge loss of crops. The annual loss of agricultural crops caused by diseases due to the attack of fungi is very heavy in India and has been esimated to be many millions of rupees. Control measures have, however, been evolved for checking the spread of diseases.

A serious disease of potato known as the late blight of potato is caused by the fungus *Phytopthora infestans*. The smut disease of wheat, barley, maize, oat and sugarcane is caused by different species of the fungus *Ustilago*. The wheat crop suffers from a variety of rust diseases caused by the rust fungi (different species of the genus *Puccinia*). They are so called because they produce on the surface of the plants they attack, masses of fine spores, which collectively give the appearances of streaks, blotches or specks of a rusty colour. The life cycles of the fungi are comparatively complex, owing to the variety of forms of spores produced by them. Some of the rust diseases of the wheat plants are: black or stem rust caused by *Puccinia graminis*; yellow rust caused by *Puccinia glumorum*; brown rust caused by *Puccinia triticinia*. All these rust diseases of wheat, crops are found in almost every parts of India where wheat is grown. Similarly many other fungi are responsible in causing diseases of other crop plants like rice, barley, oat, rye, wheat, mustard, cabbage, radish, grape vine, etc. Many fungi specially the moulds also damage vegetables, fruits and foods, particularly in storage. During the rainy season and also under moist conditions fabrics, papers, books, leather and shoes are damaged by such moulds. In view of the serious economic loss due to various plant diseases caused by fungi proper and effective control measures for controlling such diseases have been and are being devised by plant pathologists.

Although many fungi are responsible for causing diseases there are however certain other fungi which are beneficial. *Antibiotics* or the 'wonder drugs' are a group of organic substances which have been synthesized by one kind of organism that

inhibit or destroy other kinds of organisms. These antibiotics are found to check the various diseases of animals including human beings. *Penicillin*, the best known of all antibiotics was isolated in 1929 by the late Sir Alexander Flemming, the great English scientist, from a soil fungus called *Penicillium notatum*. *Penicillin*, is effectively used in the treatment of meningitis, pneumonia and several other diseases caused by pathogenic bacteria. Researches are being carried on by scientists in different parts of the world for finding out other antibiotics from various other fungi.

Ergot, a very valuable drug often used at childbirth, since it checks hemorrhages and other internal disturbances of women, is obtained from an ascomycetous fungus called ergot, which causes a serious disease in rye and other cereals. The ergot disease transforms rye grains into enlarged purplish bodies with hyphae; the bodies contain a toxic substance *ergotinine* that poisons and kills animals, including men who eat the flour of the infected grains. Ergotinine is the source of the drug ergot.

Edible fungi—There are several fungi which can be consumed as human food, and are being used as such from very early times. Many species of mushrooms (*Agaricus*), *morels* (*Morchella esculentus*) and various types of truffles (asomycetous fungi) are used as food and are popular edible fungi in Europe and U.S.A. Truffles are subterranean and in Europe dogs are trained to, locate them. The mushrooms and morels grow upon paddy straw and wheat bran, etc. in nature. They can also be cultivated. A French mycologist first published the method of cultivation of *Agaricus bisporus*, an edible mushroom in 1700 A.D. Since then different species of *Agaricus* are being cultivated in other parts of the world. The mushrooms are very nutritious and have a special flavour for which they are liked by men. They have sufficient quantity of protein, carbohydrates, minerals and vitamins. In comparison to vegetables and fruits the amount of protein in mushrooms is very much more. The cultivation of mushrooms is not difficult and in countries where there is shortage of protein food, mushrooms, if cultivated, will be very useful. Being devoid of starch, they can be used by diabetic patients. Because of the presence of different important vitamins they can also be used for different diseases like anaemia, scurvy, gingivitis, skin diseases, etc.

MUCOR

This is a common fungus which grows as a saprophyte on decaying organic matters, such as dung, bread, leather, etc. If a piece of moist bread is kept in a dark warm room for a few days, it is found that the whole surface of the bread is covered with a white web-like cottony mass commonly known as *mould*. This mass is composed of a number of filaments. All the filaments which are much branched, together form the vegetative body (the *mycelium*) of the fungus [Fig. 20]. The individual filaments are called the *hyphae* (singular, *hypha*). A number of hyphae spread over the substratum on which the plant grows, while some penetrate the substratum to draw nourishment from there.

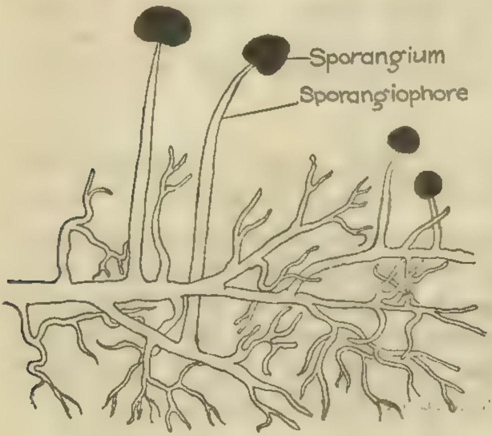


Fig. 20. Portion of a *Mucor* plant showing profusely branching mycelium and sporangiophores and sporangia.

The plant body is a *coenocyte* as no partition walls are developed and so the protoplasm in the branched tubes is continuous and multinucleate. Small vacuoles and oil globules are present. The hyphae are thin-walled and the walls are made of chitin (and not of cellulose).

Reproduction—The plant reproduces itself by two methods: *asexual* and *sexual*.

Asexual reproduction [Fig. 21]—During asexual reproduction certain hyphae grow upright. An upright hypha is called the *sporangiophore* (sporangium-bearer), because it develops a sporangium at its tip. A sporangiophore is unbranched. After it has elongated to a certain height, its tip begins to enlarge into a sporangium. Cytoplasm, many nuclei and a large amount of food stream up the sporangiophore and into the enlarging sporangium; all these form towards the outside a dense layer which surrounds a much vacuolated central portion [Fig. 21B]. A

dome-shaped layer of small vacuoles then appear between the dense and vacuolated portions of the cytoplasm [Fig. 21C]. These vacuoles become flattened and unite with one another [Fig. 21D], finally a fissure is formed between the denser and vacuolated protoplasmic regions, and at this region a wall is laid

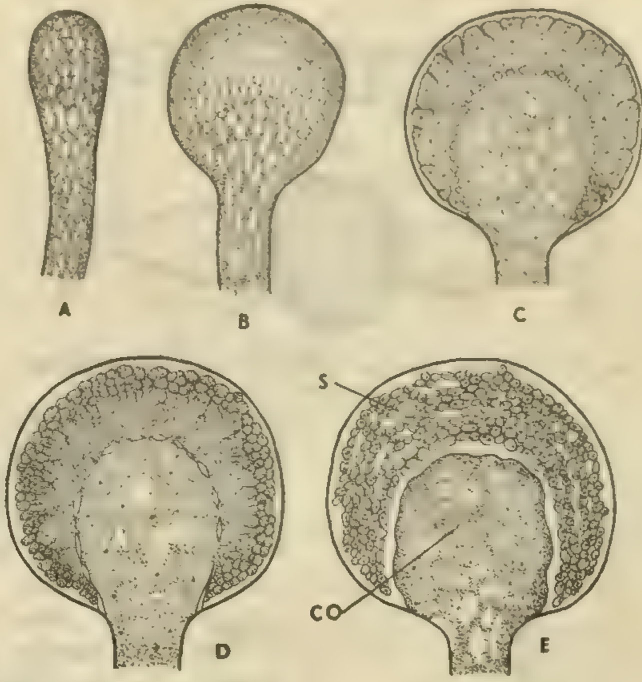


Fig. 21. *Mucor*. A-E, stages in the development of sporangium and the formation of spores. S, spores ; CO, columella.

down separating the two portions [Fig. 21E]. The dome-shaped sterile portion of the sporangium is called the *columella*. During the development of the columella the outer protoplasmic region is divided into many spores. Each spore contains many nuclei and develops a wall around itself. When the sporangium becomes mature, its wall ruptures, and the numerous spores are set free. The spores are carried by wind and on falling upon suitable substrata develop new mycelia.

Sexual reproduction [Fig. 22]—Sexual reproduction in *Mucor* takes place by conjugation and the process is similar to that of *Spirogyra*. A single plant alone or two plants if they

are exactly alike cannot carry on sexual reproduction. It can take place only when two plants of different sexes (strains) come in

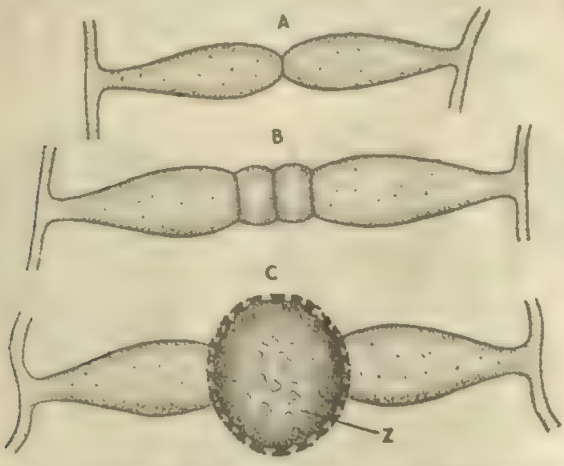


Fig. 22. Stages in the conjugation in *Mucor*. Z, Zygospore.

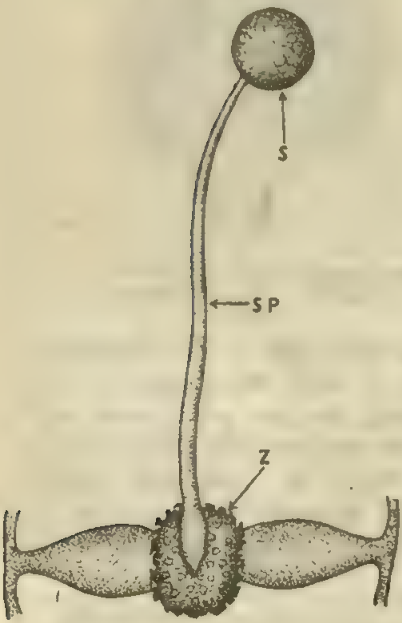


Fig. 23A. Germination of zygospore. S, sporangium ; SP, sporangiophore ; Z, zygospore.

contact with each other. The plants of the different sexes are termed plus and minus strains, although they might be called male and female. They look practically alike except that the plus strain is a little more vigorous in its growth. In the process of conjugation, pairs of club-shaped branches from the hyphae of two opposite strains are formed. At the tips of each of these branches the mass of cytoplasm with many nuclei is cut off by a cross wall and is transformed into a multinucleate gamete [Fig. 22]. The enclosed compartments containing the gametes may be called gametangia. The two gametangia meet end to end and their ends become

tightly pressed together; their end walls dissolve allowing the protoplasm of the two gametes to mingle and the nuclei to fuse in pairs. A **zygospore** (or **zygote**) is thus formed that soon becomes surrounded by a thick, black, warty wall. After a resting

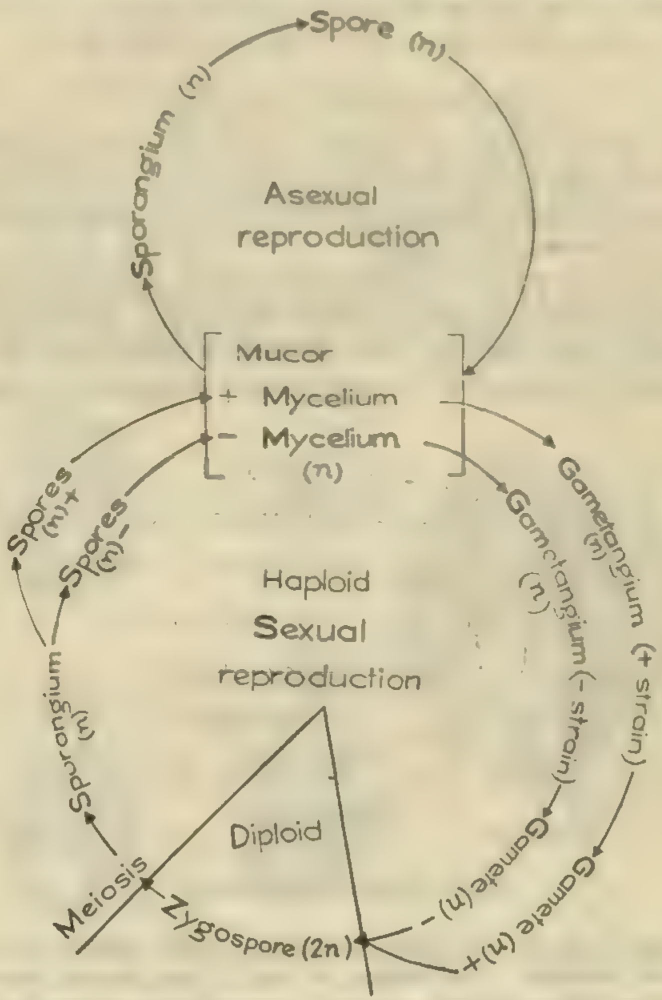


Fig. 23B. Life cycle of *Mucor* plant.

period the zygospore germinates by sending out a short, unbranched, rarely a branched hypha which bears at its tip a tiny sporangium in which asexual spores are developed [Fig. 23A]. On germination some of these spores produce plants of the plus

strain and others from the same sporangium develop plants of the minus strain.

If conjugation fails, one of the gametes may develop into a spore called **azygospore** which behaves in the same manner as the zygospore. This process is known as parthenogenesis.

The life cycle of *Mucor* plant is shown in Fig. 23B.

YEAST (*SACCHAROMYCES*)

Yeasts are simple unicellular plants which grow as saprophytes in solutions rich in sugar. They are abundantly found in such substrata like fruits, nectaries of flowers and any exudations from plant tissues containing sugar.

Each cell [Fig. 24] constitutes a single plant. Few yeast cells may remain attached to form a short chain, but they never produce a true mycelium. The cell may be spherical or oval in shape and is surrounded by a well-defined wall made up of chitin.

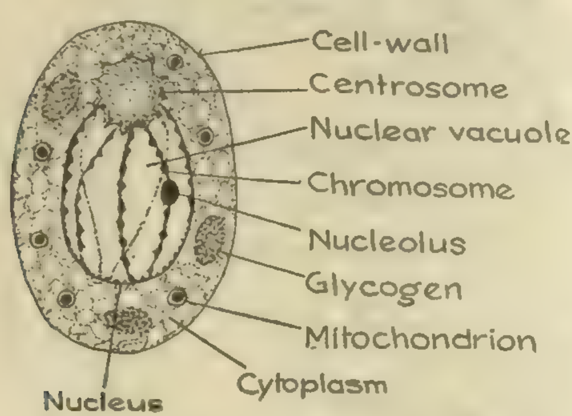


Fig. 24. Structure of a yeast cell.

It contains within it granular cytoplasm, a single nucleus and one or more vacuoles. The nucleus of yeast is not normal, because it contains a large vacuole (nuclear vacuole) within which lies the nuclear reticulum with a nucleolus. There is a centrosome on one side. Food substances in the form of rounded or angular granules are present in the cytoplasm. The rounded granules are either glycogen or fats and angular granules are protein compounds. Several mitochondria are also found.

Reproduction takes place by *vegetative*, *asexual* and also by *sexual* methods.

Vegetative reproduction [Fig. 25B-D]—Vegetative reproduction takes place by budding. In this process a small outgrowth, the 'bud' is formed at or near one pole of the cell. As the bud is developing, the nucleus divides by the process of direct nuclear division and one of the daughter nuclei passes into the 'bud'. The 'bud' gradually becomes larger and is finally separated from the mother cell by a process of constriction. During active growth the daughter cell may develop new buds before it is detatched from the mother cell, resulting in loosely connected chains.

Asexual reproduction [Fig. 25E]—When there is an abundance of oxygen the plants reproduce asexually by the production of ascospores. In this process the nucleus of a cell divides into several, usually four daughter nuclei. Cytoplasm aggregates

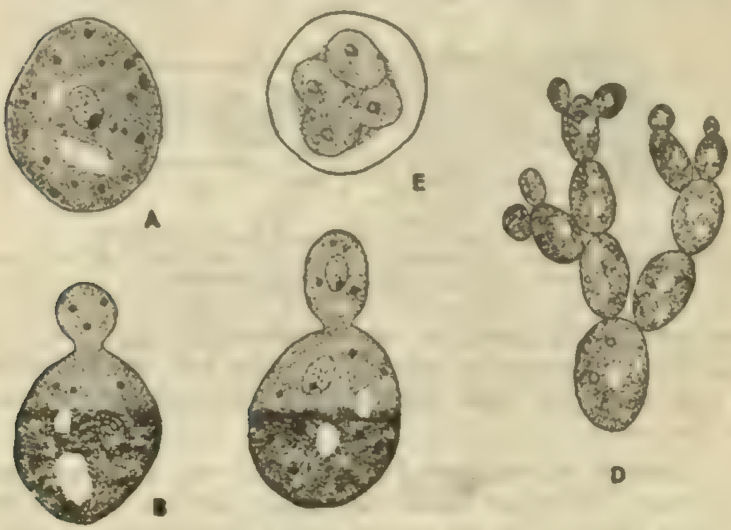


Fig. 25. A—a yeast cell ; B-D—stages in budding ; E—ascospore formation.

round each of these and four spores are formed, each with a firm wall. In some cases eight spores and sometimes less than four spores may be formed. The mother cell forming the spores is called the *ascus* and the spores *ascospores*. The spores are liberated on the disintegration of the wall of the ascus and under proper conditions, produce new yeast plants by continual budding.

Sexual reproduction [Fig. 26]—In some species of Yeast, sexual reproduction takes place by a process of conjugation. Each of the two conjugating cells sends out a short protuberance and the ends of the two protuberances unite with each other to form a conjugation tube. The two nuclei of the two cells pass into conjugation tube and there fuse with each other. After the fusion of the nuclei, the conjugation tube broadens and the entire structure

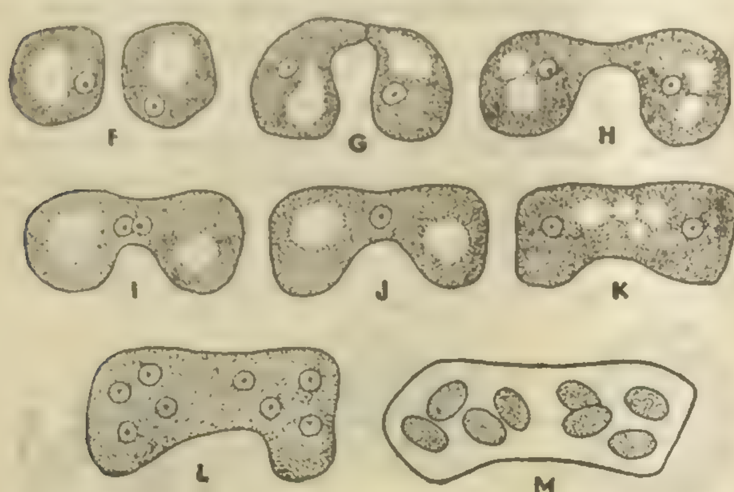


Fig. 26. Conjugation in yeast and ascus formation.
F, Two yeast cells ; G-J, successive stages of conjugation ; K—M, stages showing ascus and ascospore formation.

develops into a more or less barrel-shaped *zygospore* (or *zygote*). The zygospore becomes an ascus and develops within it eight ascospores, which become free by the rupture of the wall of the ascus.

Alcoholic fermentation—Yeasts are of very great economic importance. They are capable of inducing alcoholic fermentation in sugar solution. By this process alcohol is produced and carbon dioxide is released. The chemical change may be represented by the following equation :

$C_6H_{12}O_6$ (Sugar) $= 2C_2H_5OH$ (Alcohol) $+ 2CO_2$ (Carbon dioxide).

The fermentation process is simply a part of the respiratory process of the organisms. When oxygen is supplied, relatively little alcohol is produced.

Yeasts are also used in bread-making. They bring about

fermentation in the sugar present in the dough ; alcohol is formed which is driven off in baking and the carbon dioxide released in the process of fermentation, 'raises' the bread

Penicillium

Penicillium or blue mould is a fungus belonging to the family Aspergillaceae. They are usually saprophytic and commonly grow on decaying bread, meat, jam, leather, vegetables, fruits. Some are parasitic and cause diseases of ear, nose, throat and lung etc. of animals. A few species of *Penicillium* are used for medicinal purposes. The antibiotic penicillin is obtained from *Penicillium notatum*. A few species are used for curing cheese and giving it a special flavour.

Vegetative body : The plant body is made up of cottony interwoven threads, which are collectively known as *mycelium*.

Fig. 27A. Mycelium of *Penicillium* with a few conidiophores and conidia.

The mycelium spreads over the surface of the substratum and penetrates into it at certain places forming very fine rhizoids

(Fig. 27A), which absorb nourishment from the substratum. Each individual thread is called a *hypha* (pl. *hyphae*). The hyphae are much branched and septate. Each cell has more than one nucleus. When young the mycelium appears as a white patch, and as it grows, it becomes first pale blue, and then dull green. On account of this character, it is called a blue mould and is easily distinguished from other mould fungi.

Reproduction : *Penicillium* reproduces both by asexual and sexual methods. **Asexual reproduction** (Fig. 27B)—Asexual reproduction takes place by means of spores called *conidia*. A number of hyphae grow upright and stand erect from the mycelium. These 2-3 celled erect hyphae are known as conidiophores. Each conidiophore bears on its free end one or a few branches, known as *metulae*. Each of these branches again produces a number of closely packed branches, the *sterigmata* (sing. *sterigma*) in a whorl. Each sterigma is a slender tube like structure from the tip of which, a minute globule is cut off at first and the process is continued until a chain of globules is formed. These globules are the spores or *conidia*. The conidia are elliptical, thick walled, minutely spiny, uninucleate structures and are easily distributed by wind. The branched system of conidiophore with metulae, sterigmata and condia resembles a *penicillus*, a latin word, which means brush or broom. *Penicillium*, the name of this fungus is derived from this structure. A conidium when falls on any suitable substratum germinates and forms the mycelium.

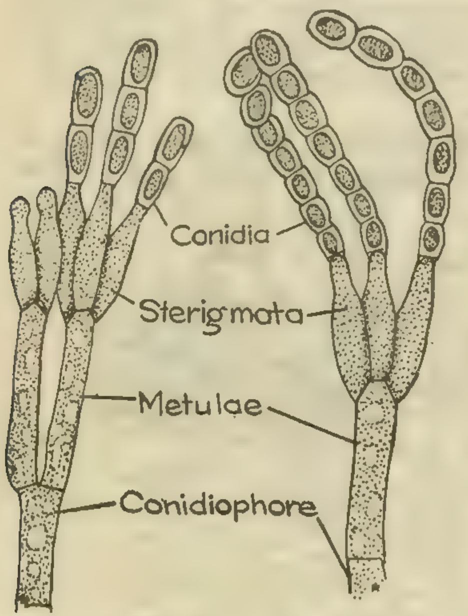


Fig. 27B. Conidia and conidiophores of *Penicillium* (magnified).

Sexual reproduction (Fig. 28)—Sexual reproduction of *Penicillium* is oogamous. The female reproductive organ is

known as *ascogonium* and the male reproductive organ as *antheridium*. The ascogonium develops from the hypha as an elongated erect structure. It is at first uninucleate but later the nucleus undergoes repeated divisions forming 32-64 nuclei. During the development of the ascogonium another branch of the vegetative hypha adjacent to the ascogonium develops the anthe-

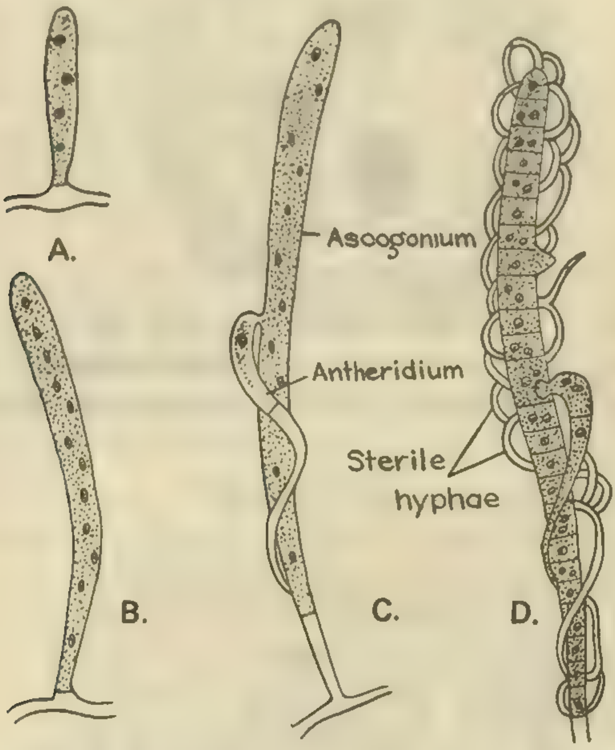


Fig. 28. Sexual reproduction in *Penicillium* showing antheridium and ascogonium. A-B, young ascogonium ; C, ascogonium and antheridium ; D, ascogonium and antheridium surrounded by sterile hyphae.

ridium. The antheridial branch coils spirally around the ascogonium up to a certain height. The terminal cell of the antheridial branch is the *antheridium*. It swells and becomes more or less club-shaped and is a uninucleate structure. Ultimately the tip of the antheridium comes in contact with the ascogonial wall and the intervening wall undergoes dissolution forming a pore. Through this pore the contents of the antheridium enters within the asco-

gonium where fusion between male and female nuclei possibly takes place. Then septation occurs in the ascogonium forming a

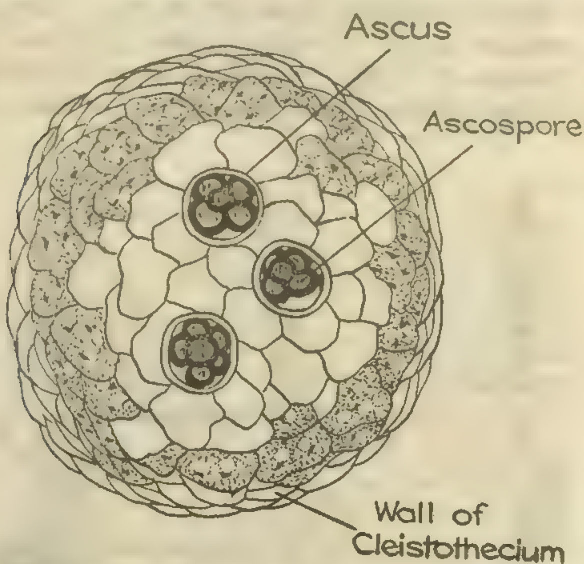


Fig. 29. Cleistothecium of *Penicillium* showing asci and ascospores.

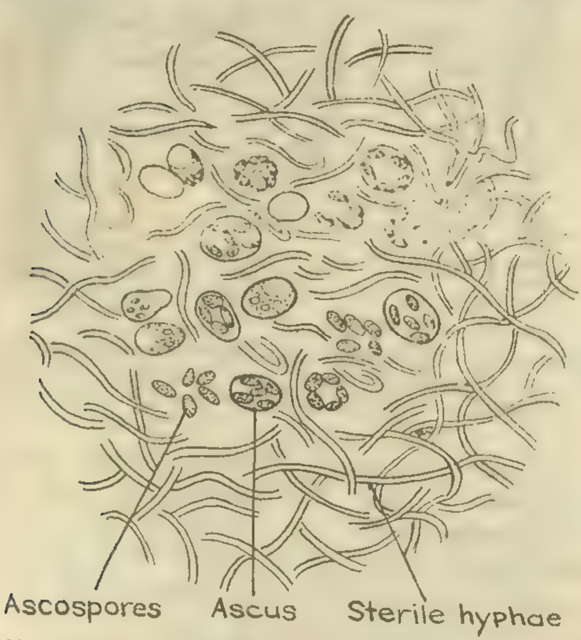


Fig. 30. Ruptured cleistothecium of *Penicillium* showing asci intermingled with sterile hyphae.

row of binucleate cells each of which then sends out one or more branched ascogenous hyphae, which are also composed of binucleate cells. The whole structure is then covered by many sterile, vegetative hyphae. Thus a fruit body (*ascocarp*) like structure known as *cleistothecium* (Figs. 29 and 30) is formed. This fruit body is a completely closed spherical structure. Within this fruit body several *asci* (sing. *ascus*), that is, ascospore bearing structures, are irregularly distributed. Each ascus is a more or less globose structure and contains 4-6, haploid, elliptical ascospores.

Penicillium is heterothallic because it produces two types of spores. The spores on germination produce mycelia. As the spores are of two types, they produce two kinds of mycelia.

AGARICUS

Agaricus, commonly known as the mushroom or toadstool, is a saprophytic fungus belonging to the group of fungi called *Basidiomycetes.* It grows on damp, rotten logs of wood, dead trunks of trees and in damp soil containing enough of decomposed leaves and other organic materials. Some forms are edible, while others are deadly poisonous. *Agaricus campestris* is a common mushroom.

The mycelium or the vegetative body of the fungus is composed of whitish, much branched, short-celled filamentous hyphae which

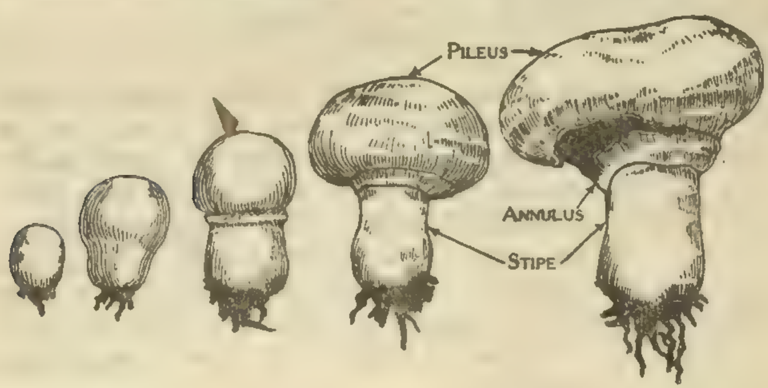


Fig. 31. Stages in the development of the fruit body of *Agaricus*.

live for the most part under the substratum. The cells of the mycelium are at first uninucleate, but later on become binucleate. Each cell has granular protoplasm with vacuoles and many oil

globules. The cell walls of the hyphae are composed of a substance called *chitin*.

The umbrella like part of the fungus seen above the ground and known as the mushroom is the reproductive structure of the fungus. It develops in the following method. After spreading for a few weeks a number of hyphae become united in clusters into branched

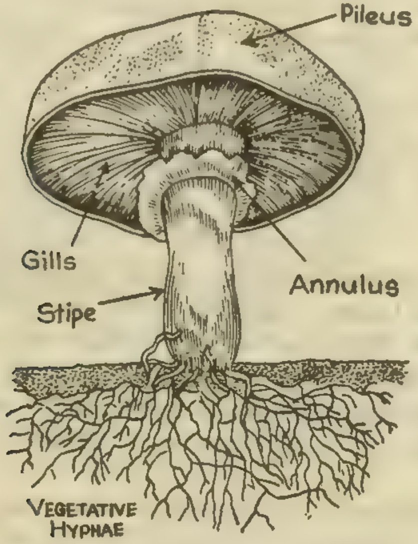


Fig. 32. A mature fruit body of *Agaricus*.

cylindrical cord-like strands. Upon the cord-like strands develops the reproductive part. At first it develops into a small oval or roundish body less than an inch in diameter. It grows rapidly and is soon differentiated into a mature *fruiting body* (also called a *sporophore*) consisting of a stalk or *stipe* and a cap or *pileus* [Fig. 31]. In the young sporophore the margin of the cap is attached to the stalk by a delicate membrane. As the stipe elongates and the pileus enlarges, this membrane is torn and only a small portion of it remains attached to the stipe in the form of a ring called the *annulus*.

The mature sporophore [Fig. 32] is about two to three inches high. The pileus is about two to five inches across; its upper surface is more or less covered with silky hairs or flat brownish scales. On the lower surface of the pileus are borne a large

number of thin vertical plates known as *gills* or *lamellae* which are arranged in a radiating manner from the pileus. The gills are at first flesh-coloured, but as the pileus grows older they become dark brown.

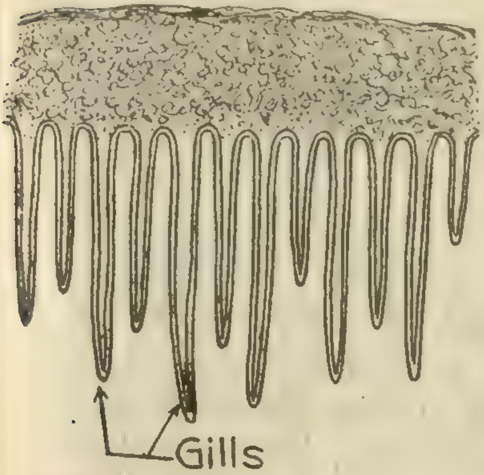


Fig. 33. A tangential section of the pileus showing the gills.

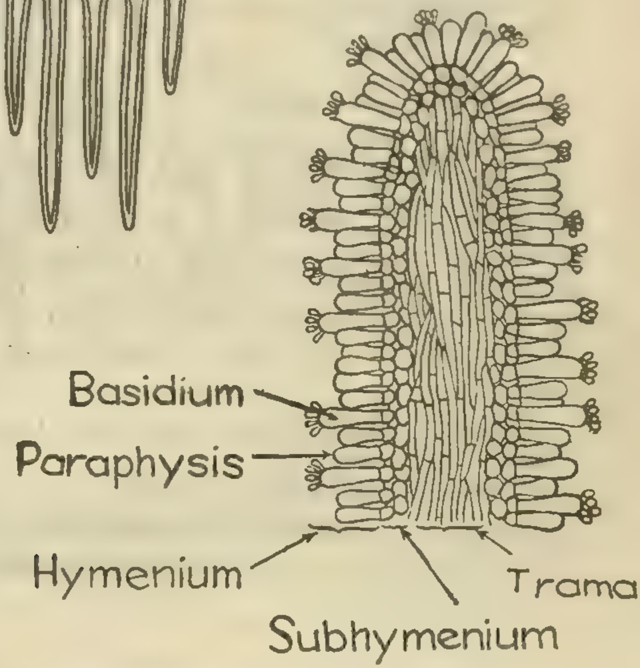


Fig. 34A. Vertical section of the gill (magnified).

Reproduction

Reproduction in *Agaricus* takes place only by means of spores known as basidiospores. These spores are edveloped on the two surfaces of the gills [Fig. 34A]. In a tangential section [Fig. 33] of the pileus the gills are cut vertically. A portion

of a single gill is highly magnified and shown in figures 34A and 34B. In each gill there is a central core consisting of loosely woven elongated septate hyphae; this is called the (i) *trama*. The segments of the hyphae of the trama diverge right and left and become divided in shorter segments forming the (ii) *subhymenium* or the *subhymenial layer*. The cells outside this layer are larger and club-shaped, and grow out at right angles to the surface; these form the superficial layer of the lamellae called the (iii) *hymenium* or the *hymenial layer*. The cells of the hymenium are packed closely side by side and are of two kinds: (i) *basidia* producing the spores and (ii) *paraphyses*, the smaller sterile cells. Each basidium bears at its apex four thin, short outgrowths, called the *sterigmata* (sing. sterigma); each sterigma bears a small spore, the *basidiospore* at its tip.

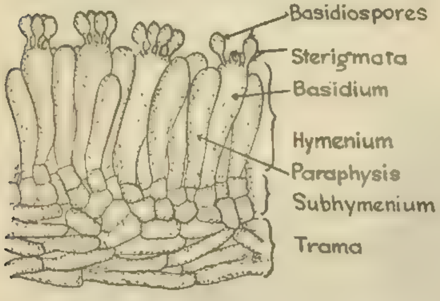


Fig. 34B. Portion of a gill (much magnified).

The basidiospore are produced in very large numbers on the hymenium. As they become mature, they are discharged from the basidia. Each spore on reaching a suitable substratrum germinates. It at first sends out a hypha, which grows vigorously, becomes branched and produces a new mycelium.

5

BRYOPHYTES

The *Bryophytes* form a group of plants constituting the liverworts (*Riccia*, *Merchantia*, etc.) and mosses. The number of species of Bryophytes is large and they are widespread in land except where there is persistent drought. The structure of their vegetative organs is best fitted for life on land, although these plants have to depend for their fertilization on external fluid water. This necessitates their growing in habitats where water will be available, at least during the time of fertilization.

Compared to the Thallophyta, these plants are higher in organisation. The sexual organs are extremely simple in the former, but not so in the Bryophytes. As the Bryophytes live on land, the ovum or the egg-cell has to be protected against the drying influence of the air. As a measure of protection the ovum is retained within the tissues of the parent plant and an archegonium is formed. The archegonium serves both the purposes of protection and nutrition of the ovum. The antheridia which produce the sperms or antherozoids are also well protected.

The most striking feature of this group of plants is that in the life-history or life-cycle of every species two distinct generations, one alternating with the other, are observed. The plant which is conspicuous is the sexual or the gametophytic generation and produces the sexual organs, archegonia and antheridia. The gametophytic generation is followed by the spore-bearing generation, called the sporophyte. In the Bryophytes the gametophyte is capable of an independent existence but the sporophyte is always dependant on the gametophyte for its nutrition.

The chromosomes in the nuclei of the sporophyte are twice as many as found in the cells of the gametophyte; that is, the gametophyte is the haploid (n) generation and the sporophyte is the diploid (2n) generation. When fertilization takes place by the fusion of the nuclei of sexual cells, the number of chromosomes become doubled in the oospore; and the number becomes again half by reduction division (meiosis) when the spores are formed.

The bryophyta has mainly two classes: Hepaticae (liverworts) and Musci (mosses). In the liverworts the body of the plant in most species is a dichotomusly branched dorsiventrally flattened thallus, as in *Riccia*, *Merchaitia*, etc. Several species are, however,

foliaceous. In the mosses the plant body is differentiated into a stem and spirally arranged leaves. Besides these there is another class of bryophyta which is known as Anthocerotae. The genus *Anthoceros* belongs to this group. It's body is a simple dorsiventrally flattened thallus.

MOSS (*POGONATUM*)

Mosses belong to the group Bryophyta, that is, plants in which the body may be differentiated into stems and leaves, but no true

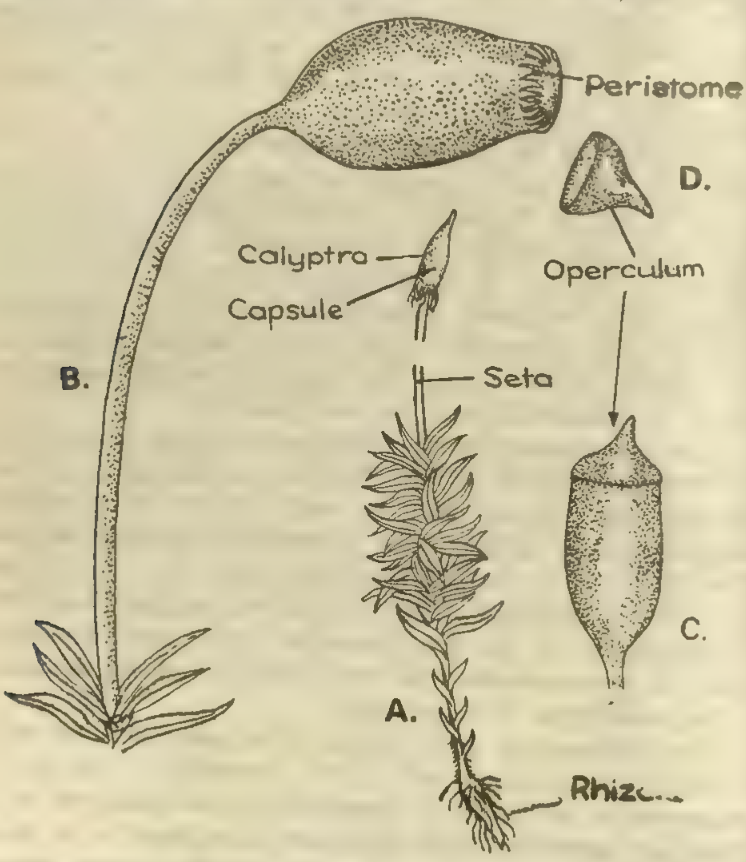


Fig. 35. *Pogonatum* plant with sporogonium. A, a mature plant (gametophyte) with sporogonium (seta partly shown) ; B, a sporogonium showing seta and capsule (with calyptra and operculum removed) ; C, capsule with calyptra removed ; D, operculum.

roots are developed. The plants grow in a colony in damp and shady places; usually they form a green carpet-like mass on old walls, rocks, barks of trees and other places.

Pogonatum (Fig. 35) is a very common moss usually found in the temperate hills of India and Ceylon. It grows on rocky soils in dense patches. The plants are small being about 3-5 centimetres in height. The conspicuous part of the plant consists of a more or less erect stem which bears a number of spirally arranged leaves. True roots are wanting; the plant develops a number of multicellular hair-like structures at its lower end; these structures called rhizoids perform the function of roots by fixing the plant in the soil and absorbing nutrients from there. The leaves of moss plants are very simple and more or less lanceolate in shape. All the cells of the leaf contain chloroplasts. The lower leaves are very small, scale like and paler in colour. The upper leaves are crowded together. The base of each leaf is broad, somewhat sheathing and paler in colour. The upper part of the leaf is deep green to brown and has a serrated margin. Most part of the leaf is occupied by a thick midrib the two sides of which is thinner and wing-like. The upper surface of the midrib is completely covered by parallel longitudinally arranged vertical plate like structures called lamellae.

Fig. 36. Apex of a branch bearing sex organs surrounded by perichaetial leaves.

Sexual Reproduction—When the moss plants attain their full size they produce gametes. The plants are therefore, called gametophores or the gamete bearing structures. The male gametes are borne in the male reproductive organs called *antheridia* and the female gametes are formed in the female reproductive organs called the *archegonia*. The leaves at the tip of the plants become specialised and are some time coloured orange or red; these leaves are clustered and together form an involucre, called the perichaetium, which appear like a flower-like head (Fig. 36). Inside this head the reproductive organs antheridia or archegonia are produced.

Moss plants may be monoecious or dioecious. Most species of the genus *Pogonatum* are dioecious; so in them the antheridia and archegonia develop on separate plants. In *Pogonatum* within a perichetium there are several antheridia but usually only three archegonia are formed. Among antheridia and archegonia

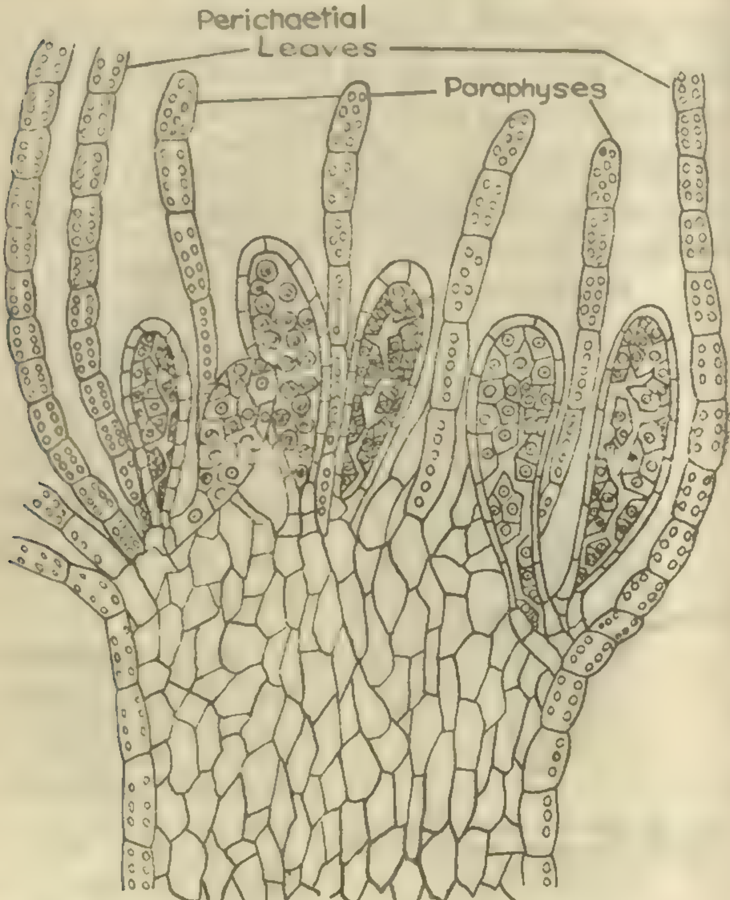


Fig. 37. Longitudinal section of the apex of a branch of moss bearing antheridia.

peculiar hair like structures called *paraphases* (sing. Paraphysis) are developed. These are multicellular and in some mosses often terminate in globular heads. The cells of the paraphyses contain chloroplasts.

The antheridium (Fig. 37) is a club shaped body mounted on a short stalk. It has a wall surrounding a cavity in which lie the antherozoids (or sperms). The cells of the wall of a young antheridium contain chloroplasts which become orange red when

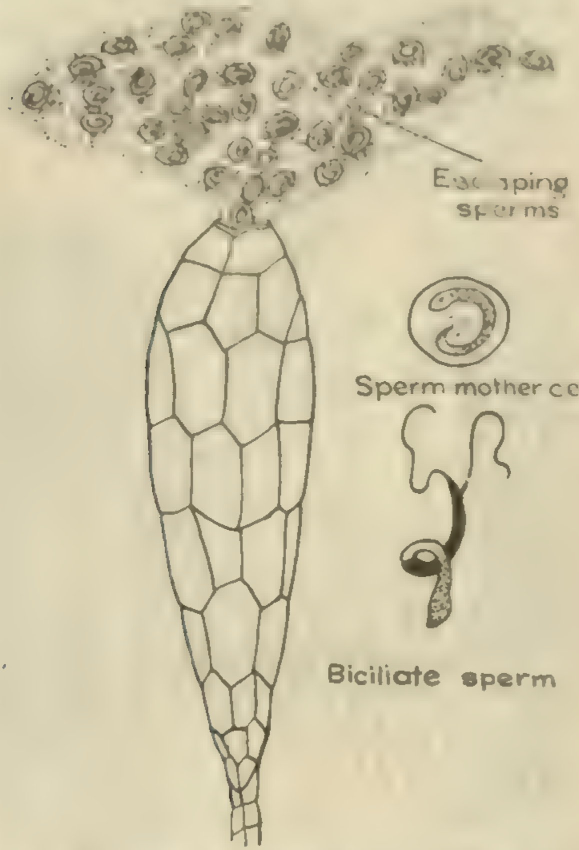


Fig. 38. A mature antheridium dehiscing at the apex; a sperm mother cell and a biciliate sperm.

the antheridium matures. The antherozoids or sperms are biciliate and each develops within a cell called the *sperm mother cell.* The sperms enclosed by the walls of the mother cells come out by splitting across the apex of the mature antheridium (Fig. 38). Very soon the mucilaginous walls of the mother cells dissolve in water and the sperms, escaping, move actively and swim away to the archegonium.

The *archegonium* [Fig. 39] is an elongated structure provided with a stalk ; it has a rather massive swollen basal portion called the *venter* and an elongated upper portion, the *neck*. The venter is surrounded by a wall which is continued upwards to form the neck. The venter contains the *ovum* or *egg* (the female gemete). Between the egg and the tip of the archegonium is a row of enclosed cells. The cell next to the egg is the *ventral canal cell* and the remainder are known as the *neck canal cells.* When the archegonium is mature the terminal cells of the neck separate ; the neck

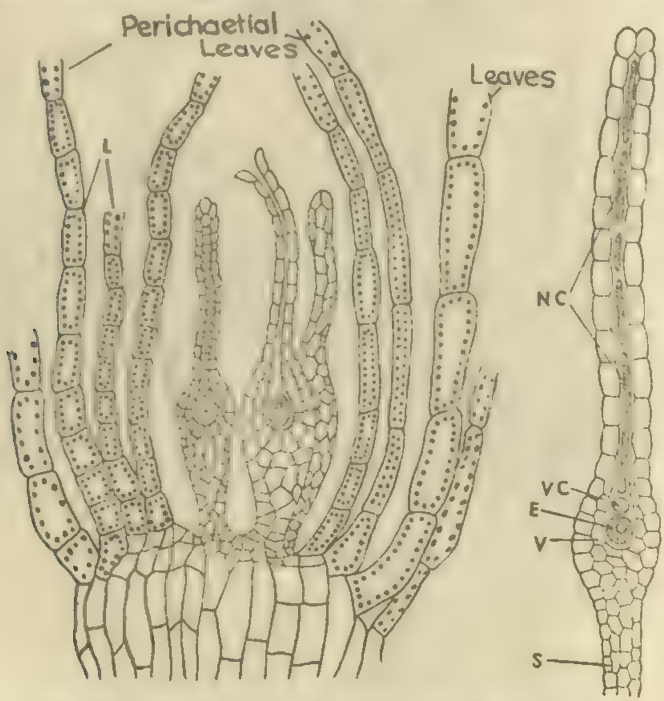


Fig. 39. Left, longitudinal section of the apex of a branch of a moss bearing archegonia and leaves. Right, a mature archegonium showing neck canal cells (NC), ventral canal cell (VC), egg (E), venter (V) and stalk (S).

canal cells and the ventral canal cell disintegrate and thus make a canal or inlet, so that the sperm can make its way down the neck to the ovum.

Fertilization can only take place when the sexual organs are moistened by dew or rain. The neck of the archegonium excretes mucilage containing cane sugar, which attracts a number of sperms,

but only one can unite with the egg. The fertilised egg surrounds itself with a wall and forms the *oospore* (or zygote).

Sporophyte. The oospore germinates at once, without becoming detached from the archegonium. It grows rapidly to form the *sporogonium* or the *sporophyte* (spore bearing organ) of the moss plant. The mature sporogonium consists of a slender stalk or seta with a capsule full of spores at its top. The seta is attached in the tissues of the moss plant by a foot. During the early growth of the sporogonium some changes take place in the archegonium whose venter grows and forms an investment to the growing sporogonium. By the elongation of the seta the investment is ruptured and is carried up on the top of the capsule in the form of a cap known as *calyptra* (Fig. 35).

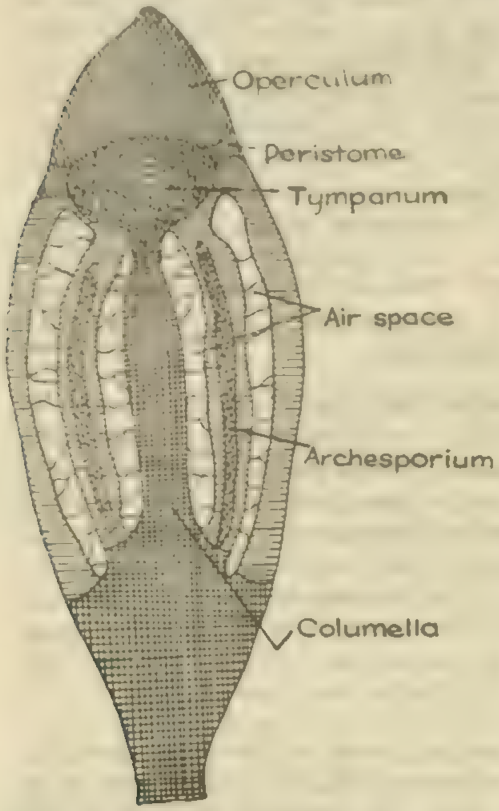


Fig. 40. L. S. of the capsule (diagrammatic) of *Pogonatum* showing different parts.

The *capsule* (Figs. 35 & 40) is a pear-shaped body which is at first bright green but brown with age. Its structure is most complicated and its ultimate function is the production of spores. It has a solid basal portion known as apophysis; at the apex of the capsule there is a lid like structure known as operculum.

The internal structure (Fig. 40) of the capsule of *Pogonatum* may be described as follows: (i) it has a solid basal portion, called

apophysis, which is the continuation of the seta. The apophysis is mainly composed of parenchyma cells containing cloroplasts. The epidermis of the apophysis contains stomata. (ii) The wall of the capsule consists of a few layers of cells, of which the outermost layer, the epidermis has thick outer wall. The cells of the inner layers contain chloroplasts. (iii) Outer air space—inside the wall there is a large cylindrical air space traversed by string like filaments of cells containing chloroplasts and connecting the wall of the capsule with the outer wall of the spore sac (iv) Next to the outer air space lies the narrow zone of sporogenous cells (archesporium or spore sac) which develop the spores. The spore sac contains an outer wall and an inner wall each having two layers of thin walled cells. (v) Inner air space—inside the inner wall of the spore sac there is another air space also traversed by filaments of cells containing chloroplasts. (vi) Columella—the central portion of the capsule is occupied by a mass of colourless parenchyma cells which form the columella. (vii) Tympanum (or epiphragm)—the columella extends and swells upward forming a drum like structure called the tympanum. (viii) Operculum—at the apex of the capsule above the tympanum there are a few layers of cells forming a sort of lid known as the operculum. (ix) Peristome—it is present just beneath the operculum.

When the capsule mature the calyptra falls off disclosing the operculum. This also finally comes away by a transverse split and the spores are dispersed. When the operculum falls off, a ring of 32 short teeth can be seen underneath; these consist of thickened walls of dead cells and are together known as the peristome. When the atmosphere is dry, they bend upwards and outwards, leaving an opening in the middle through which the spores are liberated. In wet weather the peristome teeth again become straight and close the capsule. In this way the spores are liberated when the conditions are most suitable for their dispersal.

The spores on germination produce a filamentous green alga-like body called the *protonema* [Fig. 41]. The cells of the protonema contain chloroplasts. The protonema develops branches and rapidly extends its growth over moist surfaces forming bud-like structures here and there. The leafy moss shoots (gametophores) develop from these buds. The branches of the protonema that go down into the soil, are colourless or have brownish walls, and serve as rhizoids.

Vegetative reproduction

The vegetative shoots of the gametophyte of *Pogonatum* plants grow indefinitely, specially by proliferations of the male plants. Another way of the vegetative reproduction is by the development of bud like gemmae on the rhizoids. All gametophytic parts (stem,

Fig. 41. Protonema of the moss *Pogonatum*.

leaves and rhizoids) can give rise to secondary protonemata which behave like the original protonemata. This behaviour called regeneration is very common in most mosses.

Alternation of Generations

From a study of the life-history of the moss plant it is found that there are two distinct phases or generations, viz., the *gametophytic phase* and the *sporophytic phase*, to complete the life cycle of the plant. The moss plant represents the gametophytic phase as it develops the gametes, and the sporogonium represents the sporophytic phase as it develops the spores.

In moss the two generations do not grow separately, the sporophyte develops on the gametophyte. The spores on germination produce the protonema from which the leafy moss plant (gametophyte) is developed ; the moss plant develops the male and female gametes by the union of which the sporogonium (sporophyte) is formed. Thus we find the gametophyte and sporophytic phases (or generations) alternate with each other. This phenomenon is known as *alternation of generations.*

An important distinction between these two generations is that the nucleus in any cell of the sporophyte has twice the number of

chromosomes found in the nuclei of the gametophyte. The sporophyte has, therefore, $2n$ (diploid) chromosomes and the gametophyte n (haploid) chromosomes. Throughout the gametophytic generation cell division is by the ordinary process of mitosis and therefore, the moss plant, antheridia, archegonia, sperms and eggs—all have n chromosomes. In fertilization a sperm unites with an egg thus doubling the number of chromosomes. The oospore, therefore, has $2n$ chromosomes. The oospore by ordinary mitosis produces the sporogonium which develops the spore mother cells. Reduction division takes place in the spore mother cells, each of them producing four spores. In reduction division the number of chromosomes is halved and so the spores contain n chromosomes. The spores on germination produce the protonema from which is developed the moss plant all containing n chromosomes in their nuclei. *Therefore the gametophytic generation begins with the spore and ends with the gametes, and the sporophytic generation begins with the oospore and ends with the spore mother cells.*

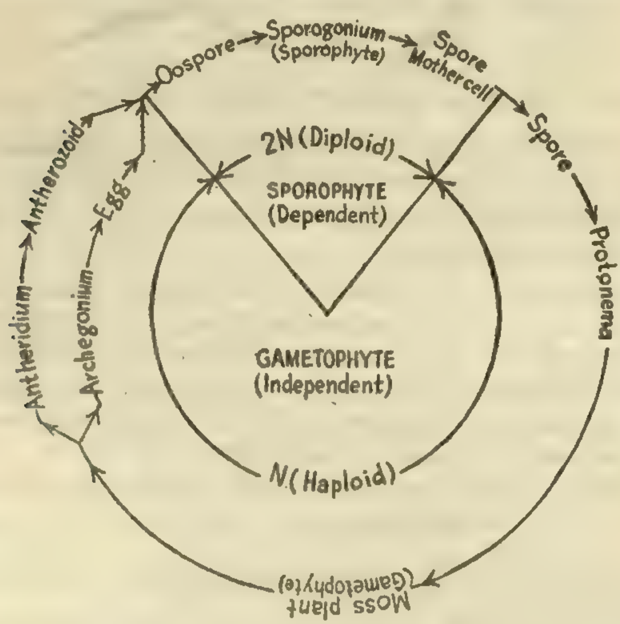


Fig. 42. Life cycle of moss (*Pogonetum*).

The life cycle and alternation of generations of the moss plant is represented in a diagram [Fig. 42].

6

PTERIDOPHYTES

The pteridophytes or vascular cryptogams, consisting of ferns, *Lycopodium* and *Selaginella,* etc. are the most highly developed Cryptogams. All members of this group possess a vascular system or central cylinder composed of xylem and pholem. The sporophyte is larger than the gametophyte and the sporophyte, although dependent on the gametophyte in its early stages of growth, is independent at maturity. Except the water ferns all pteridophytes are land plants.

Fig. 43. *Dryopteris* plant with a fertile leaf and two young leaves showing circinate vernation.

DRYOPTERIS (*Fern*)

Fern plants are widely distributed over the surface of the earth. They live in moist and shady place and are mostly perennial. There are, however, some ferns which can grow in dry places. In their general structure ferns resemble flowering plants, the plant body being differentiated into roots, stems and leaves. In the majority of ferns the stem forms a creeping or erect rhizome. In some cases it may be erect and aerial. In the tree ferns stem is woody and may attain a great

height bearing at its apex a rosette of large pinnately compound leaves.

The fern plant (Fig. 43) completes its life cycle in two alternating phases or generations which are structurally and physiologically independent of each other, the sporophytic or asexual phase and the gametophytic or sexual phase. The fern plant itself represents the *sporophytic phase* developing the spores ; the spore on germination develops a small green heart-shaped body called the prothallus; this produces the male and female gametes and represents the *gametophytic phase.*

Sporophyte

Dryopteris [Fig. 43] is a common fern growing usually in moist and shady habitats. The *stem* of the plant consists of an underground and more or less erect massive rhizome. Its surface is covered by many persistent leaf bases. The rhizome does not usually produce any branch.

The internal structure of the rhizome is rather complex. It has a superficial epidermis and a conducting system of vascular tissues (vascular bundles) which are embedded in the parenchymatous ground tissue. (a) The *epidermis* consists of a single layer of thick-walled cells. (b) *Sclerenchyma*—Just beneath the epidermis a few layers of sclerenchyma are found ; they are also found in two or three distinct patches near the centre of the stem. (c) There are a few *vascular bundles* arranged in a ring, each being surrounded by an endodermis and a pericycle. The bundles possess xylem and phloem, but no cambium. In the bundles the phloem surrounds the xylem (ectophloic *concentric*). (d) The *ground tissue* of the stem is chiefly parenchymatous.

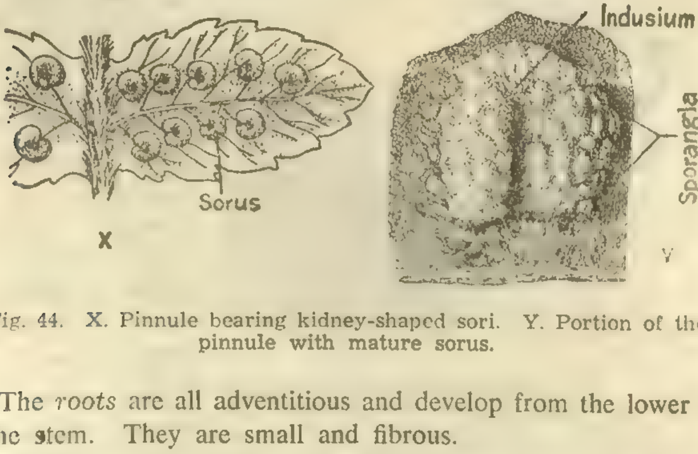


Fig. 44. X. Pinnule bearing kidney-shaped sori. Y. Portion of the pinnule with mature sorus.

The *roots* are all adventitious and develop from the lower side of the stem. They are small and fibrous.

The *leaves* are large and pinnately compound. The leaflets are called *pinnae ;* the pinnae are further divided and their ultimate

divisions are known as *pinnules*. The vernation of the leaf is circinate. Fern leaves are often called *fronds*. They continue to grow at their apices until their full size is attained. The stem and leaves, especially when they are young, are often densely covered with many brownish scales called *ramenta* (sing. *ramentum*) which protect the young parts against drought.

Sporangia and spores—The sporangia are usually produced in large numbers on the underside of certain leaves. Leaves producing sporangia are called *sporophylls*; the sporophylls of ferns resemble the foliage leaves. A number of sporangia are grouped together forming what is known as a *sorus*, (plural *sori*). The

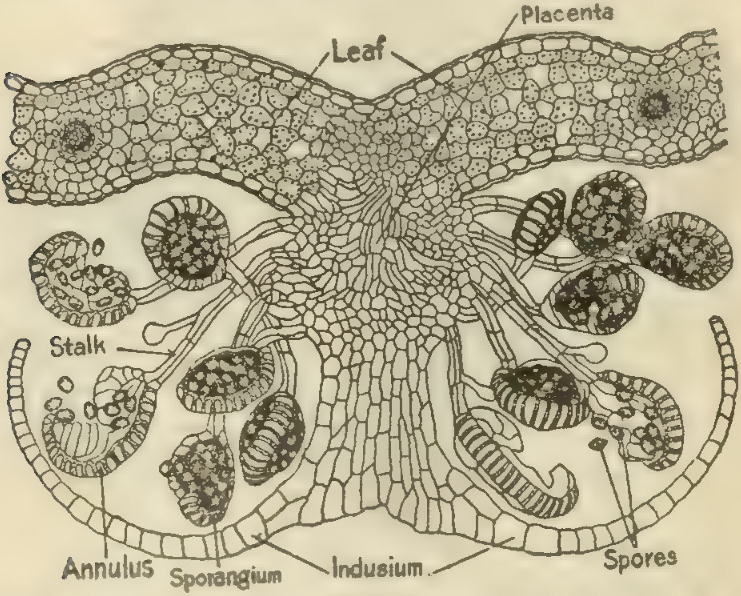


Fig. 45. Cross section of a *Dryopteris* leaf through a sorus.

sori appear as small kidney-shaped projections arranged in two rows on each pinnule. [Fig. 44]. They are at first light green in colour, but when mature, become brown. The sporangia are borne on a projection of the pinnule called the *placenta* and are covered by a protective membrane called the *indusium* which is also an outgrowth from the placenta. [Figs. 44 & 45].

The fully developed sporangium [Fig. 45] consists of a *stalk* and a *capsule*. The capsule is oval in outline and is biconvex. Its wall is composed of a single layer of thin-walled cells; but the

cells round the edge are large and specially thick-walled and constitute the *annulus*. The annulus in most cases does not extend completely round the sporangium; between the end of annulus and the stalk are a few thin-walled cells which form the *stomium*. Inside the capsule there is a brown powdery mass consisting of 64 spores. When the sporangium is mature the walls of the cells forming the annulus lose water and by their contraction the sporangium wall bursts at the stomium, and the spores are set free.

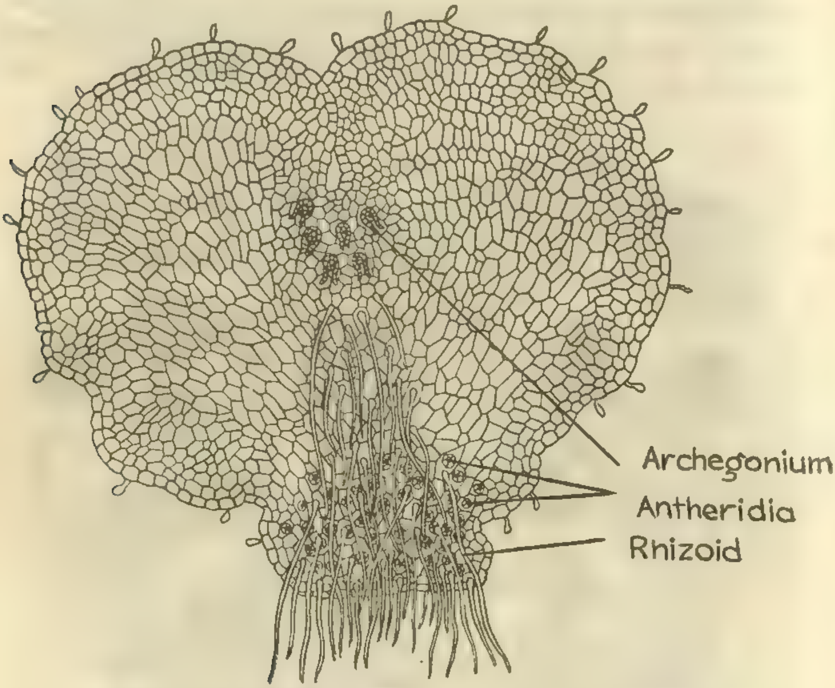


Fig. 46. Mature gametophyte (prothallus) of fern (*Dryopteris*) as seen from the under surface, bearing antheridia among the rhizoids and archegonia below the apical notch.

(Within each sporangium the tissue to give rise to the spores is organised into a number of 16 large cells which are called the spore-mother cells. Reduction division takes place in the spore-mother cells and as a result each of them forms a tetrad (group of four) of spores. *With the formation of spores the sporophytic or asexual generation ends and the gametophytic or sexual generation commences.* The spore containing the *n* chromosomes is, therefore, regarded as the first cell of the gametophytic generation).

Gametophyte

Each spore is a very small one-celled body provided with a thick outer coat (*exine*) and a thin inner coat (*intine*). Under

favourable conditions of moisture and temperature the spore germinates. The exine bursts and the intine grows into a green filament attached to the soil by one or more rhizoids. This green filament then widens out and finally develops into a small (1/8 to 1/3 inch in diameter), flat, heart-shaped green body which is called the *prothallus* (or *prothallium*) [Fig. 46]. The prothallus is attached to the soil by many unicellular rhizoids which develop on its lower surface. It is an independent plant. By means of the rhizoids it can absorb water and nutrient salts from the soil and its cells containing choroplasts can manufacture food by absorbing carbon dioxide from the atmosphere.

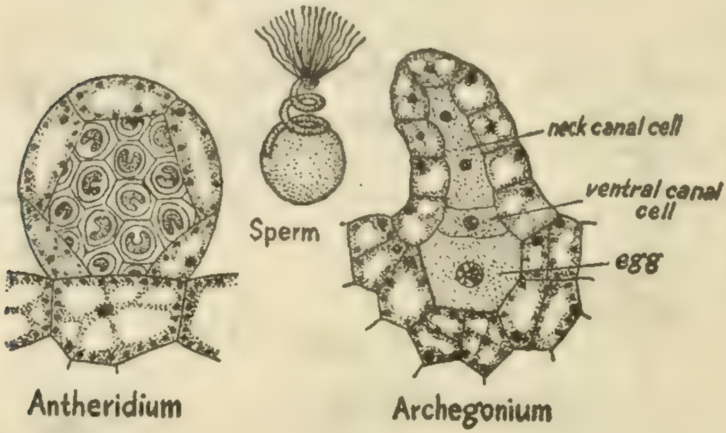


Fig. 47. Left, an antheridium ; Middle, a sperm ; Right, an archegonium.

The *antehridium* [Fig. 47] is a spherical body, the wall of which consists of a single layer of chlorophyll-containing cells. Each antheridium contains a number of small cells called *spermatocytes* (sperm-mother cells), each of which gives rise to a single spirally coiled *sperm* (or *antherozoid*) bearing a number of a cilia [Fig. 47] (not two as in the mosses).

The *archegonium* [Fig. 47] is a flask-shaped structure consisting of two parts, a swollen basal portion, the *venter* and an elongated upper portion, the *neck*. The archegonium differs from that of a moss in that it is shorter and that the venter is embedded in the tissue of the gametophyte. The neck is not straight, but bends on one side. The neck consists of a wall consisting of a single layer of cells enclosing a single binucleate *neck canal cell.*

The venter contains the large *ovum* or *egg cell* and the *ventral canal cell* immediately above it.

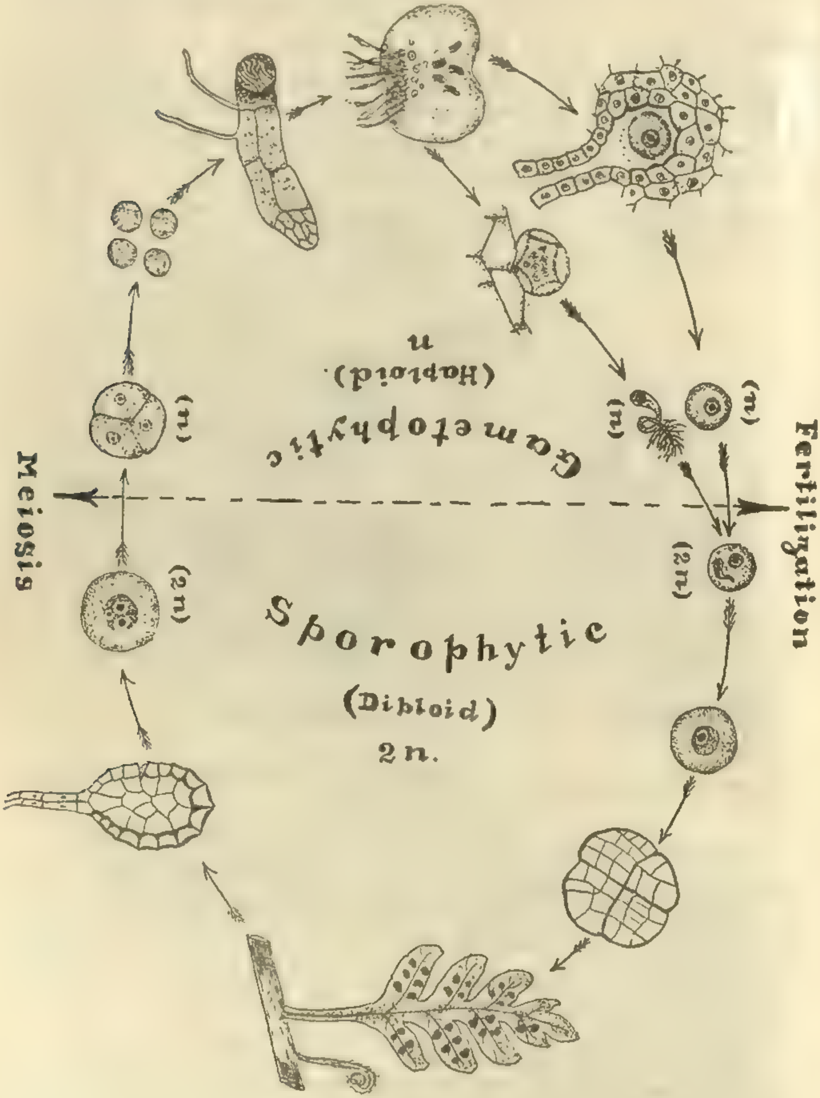


Fig. 48. Life cycle of fern.

Fertilization takes place only in the presence of water. The antheridia open and discharge the sperms in water. At about the same time the neck canal cell and the ventral canal cell

disintegrate into a mucilaginous mass, which absorbs moisture and swells, rupturing the tip of the archegonium ; thus a continuous passage is formed to the ovum which is now ready for fertilization. The mucilaginous substance containing a little malic acid is discharged into the water. The sperms stimulated by the acid swim to the neck of the archegonium and move down through the canal to the egg cell. A number of sperms may be attracted to one archegonium and may pass down the canal, but only one fuses with the egg. The fertilised egg surrounds itself with a wall and forms the *oospore* (*zygote*).

Young sporophyte—Immediately after fertilization the oospore by repeated divisions gives rise to an embryo which ultimately develops into a new fern plant. In the early stages of its development the young fern plant entirely depends upon the prothallus for its nourishment.

The life cycle and alternation of generations of the Fern Plant is shown in a diagram [Fig. 48].

Comparison of the life-cycles of a Moss and a Fern

MOSS		FERN
Spore (n)	Gametophytic Generation	Spore (n)
Protonema (n)		
Moss plant (n) (Gametophyte)		Prothallus (n) (Gametophyte)
Antheridium (n) — Archegonium (n)		Antheridium (n) — Archegonium (n)
Sperm (n) Ovum (n)		Sperm (n) Ovum (n)
Oospore (2n)	Sporophytic Generation	Oospore (2n)
		Fern plant (2n) (Sporophyte)
Sporogonium (2n) (Sporophyte)		Sporophyll (2n)
		Sporangium (2n)
Spore mother cell (2n)		Spore mother cell (2n)
Spore (n)		Spore (n)

7

GYMNOSPERMS

Distinctive features

Distinctive Features—The gymnosperms are plants in which the seeds are not enclosed in fruits. They occupy an intermediate position between vascular Cryptogams and Angiosperms and are regarded as the most primitive of all seed plants. They were very predominant in the early geological era (see Geological Time Table, opposite p 264, Part 1), but now form an insignificant portion of the plant kingdom of the present day. Most of them have become extinct and are found in fossil forms. The living representatives of this group appear rather isolated and distinct from one another. The common living genera of Gymnosperms are *Cycas* and *Pinus*. Gymnosperms are all woody perennial plants. The xylem of the vascular bundles except in very few cases does not contain any vessel, but simply tracheids. The phloem is composed mainly of sieve tubes; companion cells are absent.

Like *Selaginella*, the plants are heterosporous; the two kinds of spores known as microspores and megaspores are associated in two kinds of sporophylls, microsporophylls (or stamens) and megasporophylls (or carpels). Specialization in this case has gone further and the two kinds of *sporophylls* are grouped in separate *strobili*, staminate or male strobili and carpellate or female strobili. Each *microsporophyll* bears two or more *microsporangia* (or *pollen-sacs*) each of which develops within it a number of *microspore mother cells*; each mother cell develops into four *microspores* (*or pollen grains*). The *megasporophylls* or *carpels* do not produce a typical pistil consisting of ovary, style and stigma, but remain as flat expanded structures, on which are borne the *megasporangia* (or *ovules*). The *megasporangium* develops a single *megaspore mother cell* which divides to form four *megaspore;* three of them soon disintegrate, and only one persists. In pollination, the microspore (pollen grain) is transferred directly to the micropyle of the ovule where it develops a pollen tube (*male gametophyte*), in which two *male gametes* are developed. By a series of nuclear divisions the megaspore develops within it a large number of nuclei. Later by the formation of cell walls a many-celled tissue (female gametophyte) is formed. Two or three archegonia each containing a single large *egg* are usually found at the micropylar end of the gametophyte.

Fertilization and seed formation—The pollen tube with two male gametes grows through the tissue of the megasporangium towards the female gametophytes. When it reaches the opening of the archegonium, its tip bursts and discharges the gametes; one of the two gametes fuses with the egg, while the other one is disorganised. The fertilised egg or oospore (containing the $2n$ *chromosomes*) develops into an embryo; the vegetative cells of the female gametophyte are transformed into a nutritive tissue called *endosperm;* and the integument forms a seed-coat. From the seed a new plant is developed.

PINUS

Among the gymnosperms the genus *Pinus* (popularly known as the pines) is the most familiar. Pine trees grow abundantly in

the eastern and western Himalayas at an altitude of 1000 to 3500 meters. The commonest species of *Pinus* is *Pinus longifolia*. *Pinus khasya* is also another common Indian species of Pines, which grows in the Khasya hills of Meghalaya.

Fig. 49. A, Branch of a pine plant with several male cones. The scale leaves and the needle leaves in short shoots are seen. B, A microsporophyll with microsporangia.

The plants are tall erect evergreen trees somewhat symmetrical and often with a characteristic pyramidal shape. The main stem is quite straight, growing more strongly than the lateral branches and can be traced from the ground to the top of the tree. In the young stages the plant has a well developed tap root, but this tap root becomes lost in branch roots which attain equal size. The

stem produces numerous lateral branches with green thick needle-like leaves. Two kinds of branches, long branches and dwarf branches or spur shoots are formed. The long branches are completely covered by brown scale leaves. From the axils of the scale leaves the dwarf branches each having usually 3 to 8 leaves in cluster, develop (Fig. 49A). Leaves are of two kinds, namely the brownish scale leaves borne by the long branches and the needle-shaped foliage leaves. Pine leaves persist for several years after which they are shed with the spur shoots which bear them. The arrangement of the leaves is unique amongst all conifers. In the seedlings they are borne singly and are spirally arranged on the stem. After a growth of about two years the pine plant begins to produce its leaves in clusters. Each cluster containing usually three to eight long needle-like leaves is enclosed at the base by a series of short scale leaves. This form the short shoots or dwarf branches of the stem in which there is no apical growth, that is, the activity of the apical meristem is suspended.

In contrast to the angiosperms, vegetative reproduction in Pines, as in all gymnosperms, is extremely rare.

Internal Structure of the stem—The structure of the young stem resembles that of a dicotyledonous plant in many respects. The general arrangement of the tissues from the outside to the centre of the stem is given below.

(i) Epidermis consisting of a single layer of cells with thick cuticles and irregular outline.

(ii) The cortex is a fairly broad zone consisting of parenchyma cells, many resin ducts are uniformly distributed in the cortex.

(iii) The vascular bundles are collateral and open ; they are arranged in a ring. Phloem consists of sieve cells and phloem parenchyma ; companion cells are absent. Cambium is present between phloem and xylem. Xylem consisting of protoxylem and metaxylem. Protoxylem consists of annular and spiral tracheids disposed towards the centre. Metaxylem consists exclusively of tracheids with bordered pits. Vessels are absent. Cambium consists of a few layers of thin walled cells (rectangular in transverse section). The pith is well developed and consists of parenchyma cells.

In the pine, secondary growth begins early and leads to the formation of massive amounts of secondary xylem consisting mainly of thick walled tracheids with bordered pits, through which narrow medullary rays, consisting of thick walled parenchyma cells with simple pits, extend centrifugally. The cork cambium soon arises in the cortex and gives rise to the cork on the outside and some parenchyma on the inside.

Internal structure of pine leaves—The leaves of pines are suited for growth under xerophytic conditions. The epidermis forms a single layer of very thick walled cells covered with a thick cuticle. The stomata are sunken, opening into a respiratory cavity. Hypodermis consists of 1 to 3 layers of thick walled cells.

The mesophyll is compact with few air spaces and consists of large thin walled polygonal or irregular cells containing abundant chloroplasts.

There are peglike projections of the cell walls into the cell cavity of each mesophyll cell. In the mesophyll some resin ducts are present. The central portion of the leaf is delimited by a conspicuous endodermis within which usually two vascular bundles are embedded in the tissue called the transfusion tissue which is regarded as reduced vascular tissue.

Pine plants are monoecious. It bears two kinds of cones or strobili (sing. strobilus), male and female, on separate branches of the same plant.

The male cones [Fig. 49A] are relatively small, usually being 1 to 2.5 centimeters in length. They appear in a cluster each in

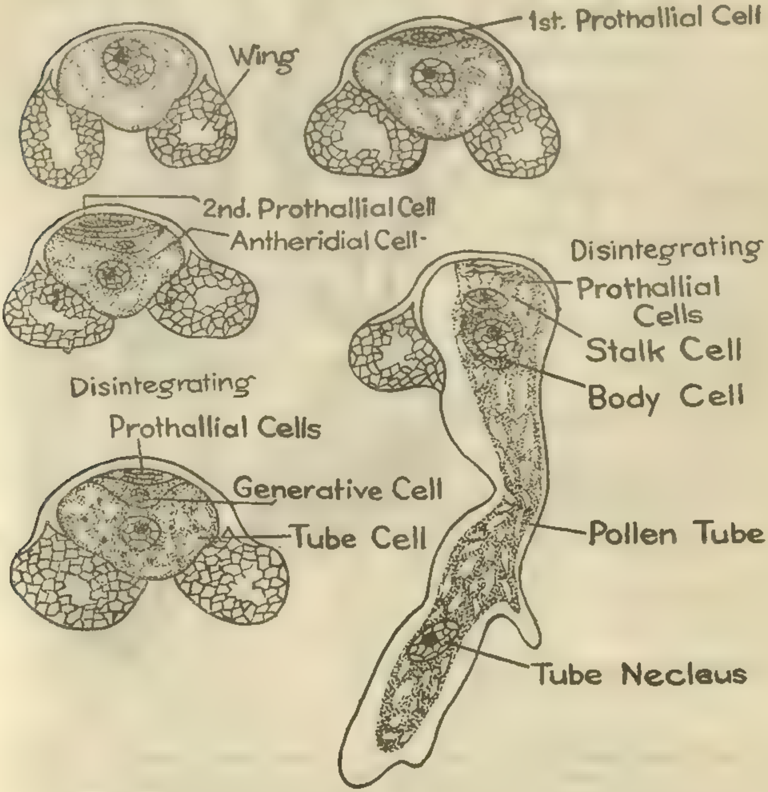


Fig. 50. Stages in the germination of microspore and development of the pollen tube.

the axil of a scale leaf. Each cone is a cylindrical body consisting of a central axis bearing the microsporophylls, which are spirally arranged and more or less membranous in texture. Each bears

two pouch-like microsporangia (anthers) on its lower side (Fig. 49B). Within the microsporngia, there are numerous microspore mother cells, each of which undergoes reduction division and produces a tetrad of microspores or pollen grains. The microspores or pollen grains are produced in large numbers. Each pollen grain has two

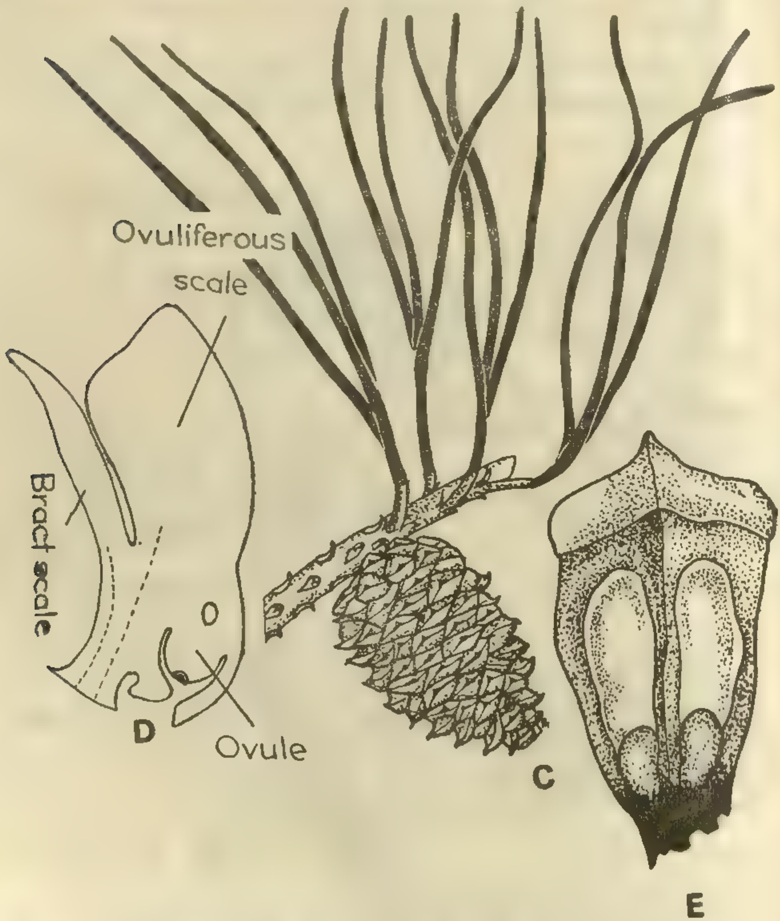


Fig. 51. C—Branch of a pine tree with one female cone, D—section through a ovuliferous scale showing bract scale, ovuliferous scale and the ovule, E—megasporophyll with two mature seeds with wings.

coats: at maturity the outer coat forms two large air sacs or bladders on each side of the grain. In the fully mature pollen grain four cells are distinctly seen. The large amount of pollen which are produced by a single tree is surprising. The pollen grains are shed in enormous quantities and are carried by wind.

In pine forests the grains often from conspicuous yellow patches on the ground or on the surface of lakes and ponds.

Male gametophyte—The microspore or pollen grain begins to divide before it is set free from the microsporangium or pollen sac. It divides into two extremely reduced small cells called the prothallial cell and an antheridial cell. The prothallial cell soon becomes disorganised. The antheridial cell divides and form a generative cell and a tube cell (Fig. 50). The pollen grain is shed at this stage.

The female cones are much larger and occur singly and not in clusters (Fig. 51C). The young cone consists of a central axis upon which the megasporophylls are arranged spirally. Each megasporophyll is composed of a short stalk and a scale known as the ovuliferous scale. On the underside of this scale there is a smaller scale known as the bract scale (Fig. 51D). At the base of the ovuliferous scale there are two avules on its upper surface (Fig. 52 left). Each ovule is composed of a mass of tissue—the nucellus, surrounded by a massive single integument with the micropyle towards the base. The embryo sac or megaspore remains embedded in the nucellus.

Megagametophyte or Female gametophyte (Fig. 52 right)—The embryo sac or megaspore divides and gives rise to the female

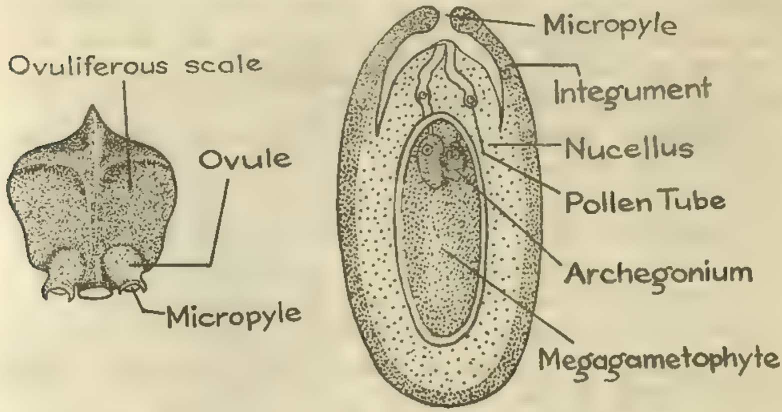


Fig. 52. Ovuliferous scale and the female gametophyte.

gametophyte within the nucellus. It enlarges considerably by digesting a large portion of the nucellus. By a series of nuclear divisions, the megaspore develops within it a large number of nuclei. Later by the formation of cell walls a many celled tissue,

called *endosperm* is formed. Towards the end of the year, after pollination has taken place, 2-5 archegonia arise in the female gametophyte towards the micropylar end (Fig. 52). Each archegonium consists of a swollen venter and short neck. It consists of 8 small neck cells in two groups of 4, a ventral canal cell and a large egg cell. The ventral canal cell disintegrates before fertilization occurs. There is no neck canal cell.

When the development of female prothallus is going on, the male porthallus (pollen grain) completes its development.

Pollination—Pollen grains are produced in large quantities. The air sacs facilitate the floating of the pollen grains in large number in the air. Some of them get into the female cone and reach the pollen chamber at the base of the micropyle. When the female cones are ready for fertilization, the scales remain wide open. Pollination in pine is really the lodging of the pollen grains in the pollen chamber. After pollination the scales close up without leaving any passage.

Fertilization—The outer coat of the pollen grain bursts and the inner coat grows out into a pollen tube (Fig. 52 right). The pollen tube passes through the nucellus (Fig. 52 right), and finally reaches the canal of the archegonium ; the generative cell divides and forms a stalk cell and body cell. The body cell divides and produces two male gametes. The pollen tube bursts at the apex and the two male gemetes are liberated. One male gamete unites with the egg nucleus and the other male gamete, the stalk cell and the tube nucleus disintegrate.

The new sporophyte—Just after fertilization the resulting zygote starts division. Due to two quick divisions four free nuclei are produced. These nuclei pass to the base of the cell where each one divides again. Now walls are formed. These cells undergo further division forming four tiers, each consisting of four cells. The lowest tier forms the embryo. The next upper tier elongates to form the suspensor. The four cells of the lowest tier may together form one embryo or each of them may form a single embryo. (Fig. 54 bottom, right)

There are several archegonia in each ovule and all of which may be fertilised. So a single seed may contain several embryos. This condition is known as *polyembryony*. But usually only one embryo develops and the others disintegrate. A ripe seed develops a large membranous wing which splits off from the ovuliferous scale.

An young embryo (Fig. 53) consists of a radicle, a hypocotyl, cotyledons and a small plumule ; the number of cotyledons usually varies from 2 to 15. The radicle is well developed and is very large. The seed is albuminous, but the origin of its endosperm is different from that of angiospermic seed. With the expansion of the endosperm the nucellus usually becomes crushed. The integument forms the seed coat and the ovule develops into a seed. The process of pollen germination and fertilization are of longer duration in Pines than in other seed plants. The formation of the seed and the maturing of the cones are prolonged for nearly a year.

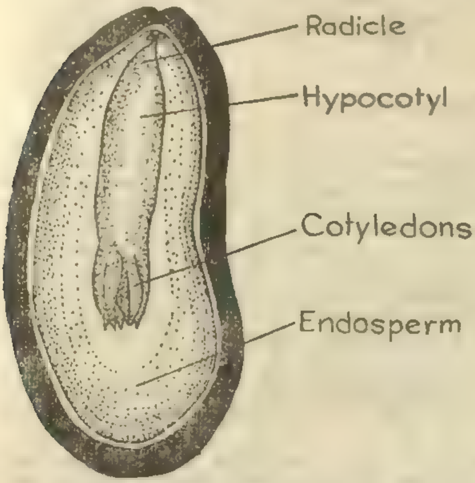


Fig. 53. Longitudinal section through a pine seed with its seed coat, endosperm and embryo, showing the hypocotyl and several colyledons.

The complete life cycle of *Pinus* is shown in Fig. 53A.

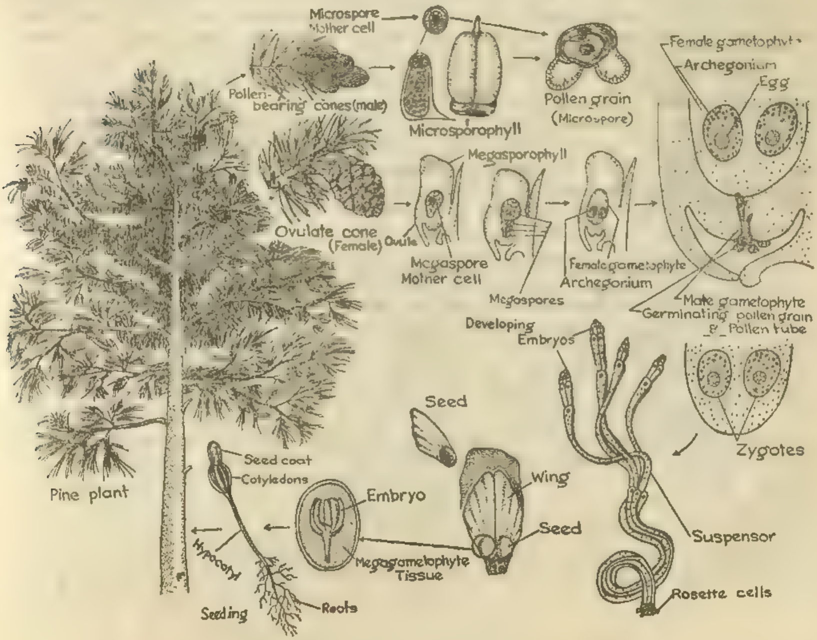


Fig. 53A. Life cycle of *Pinus*.

8

ANGIOSPERMS

Distinctive features—The angiosperms are regarded as true flowering plants producing typical flowers provided with perianth leaves; their ovules are enclosed within ovaries. The angiosperms comprise a large and diverse group of plants, except the open ocean. They include aquatic types, parasitic types, saprophytic types and partly carnivorous types. They are the essential food producing plants and supply food to all terrestrial life. There are however some angiosperms with are very poisonous. Many angiosperms are conspicuous for the beautiful colour of their flowers. Many of them are medicinal; important life-saving drugs are obtained from them.

The angiosperms may be annuals growing only for one season; there are others which grow for many years; a few angiosperms have been found to live for centuries.

They show a great variation in their size, form and structure and reproductive features. In the xylem of angiosperms vessels are present, which are, however, absent in the pteridophytes and gymnosperms; in the phloem both sieve tubes and companion cells are present, companion cells being absent in the two other groups.

Sporophylls, Sporangia and Spores—The plant is the sporophyte. At maturity it develops the flowers. The flowers may be *bisexual* that is, possess both stamens and carpels, or *unisexual*, that is, some bear stamens, others carpels. The stamen, also called a *microsporophyll*, bears an anther containing usually four *pollen sacs* or *microsporangia* (pages 22-244, Figs. 120, 121 & 122; Part I). In each microsporangium a number, of *microspore mother cells* (having $2n$ chromosomes) are developed, from each of which four *microspores* (*pollen grains*) are formed by a process of reduction division (see pages 85-90. Fig. 40; Part I). Each microspore contains, therefore, the 'n' chromosomes. A *carpel* also called a *megasporophyll*, or a number of them are organised into a *pistil* (consisting of an ovary, one or more styles and one or more stigmas). The ovary encloses within it one or more ovules. The ovule is also called the *megasporangium* and is enclosed by one or two integuments. Within the megasporangium a single *megaspore mother cell* is developed. By the process of reduction division four megaspores are formed from the mother cell. Each megaspore has, therefore the 'n' chromosomes.

Male and female gametophytes—The gametophytic generation begins with the microspores and megaspores having the 'n' chromosomes. *Male gametophyte*—The microspore (pollen grain) is at first uninucleate. The nucleus divides and two naked cells, tube cell and a *generative cell*, are formed. It is usually in this condition that the pollen is transferred to the stigma of the same or of a different flower. Shortly after reaching the stigma, the tube cell grows out into a *pollen tube*, and the nucleus of the generative cell divides to form two *male gametes*. The pollen tube may, therefore, be called the *male gametophyte*. *Female gametophyte*—By three successive divisions eight nuclei are formed in the embryo-sac (see pages 220-222, Figs. 120, 121 & 122; Part I). The embryo-sac containing these eight nuclei is the female gametophyte.

Fertilization—The process of fertilization and the formation of the seed have already been described in pages 220-222. (Part I). In fertilization the number of chromosomes is doubled and the *oospore*, containing the

$2n$ chromosomes develops into an embryo consisting of a radicle, a plumule, and one or two cotyledons. By a series of divisions of the *endosperm nucleus* a large number of nuclei are formed; with the formation of cell walls, these are organised into a tissue, called *endosperm*. The embryo remains within a *seed* developed from the ovule. The ovary is then transformed into a *fruit*. With the germination of a seed, the embryo develops into a *new plant (sporophyte)*.

Alternation of Generations—The life cycle and alternation of generations in an angiosperm is shown in Fig. 54.

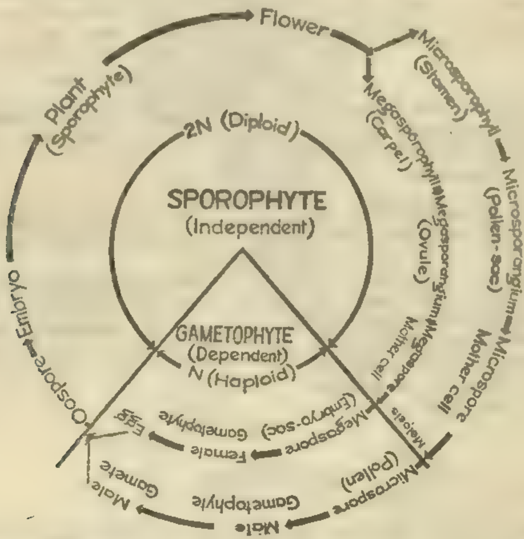


Fig. 54. Diagram showing life cycle of an angiosperm and the alternation of the two generations.

Dicotyledons and Monocotyledons—a comparison

The Angiosperms comprise the largest number of higher plants and are divided into two classes: Dicotyledons, and Monocotyledons.

These two great groups are quite distinct and can be easily distinguished by their external and internal structures. Usually there is no difficulty in recognising them. The chief characteristics distinguishing the two groups may be given as follows:

Dicotyledons	*Monocotyledons*
1. Embryo with two lateral cotyledons and terminal plumule.	1. Embryo with a single terminal cotyledon and lateral plumule.
2. The primary root persists and develops into a tap root.	2. The primary root dies early and is replaced by a number of fibrous roots developing from the base of the stem.

Dicotyledons	*Monocotyledons*
3. Venation of leaves is reticulate, rarely parallel, as in *Calophyllum*.	3. Venation of leaves is usually parallel, rarely reticulate, e.g. in Arum, *Smilax* and Yam.
4. Floral members are usually five or four in each whorl (pentamerous or tetramerous).	4. Floral members are usually three in each whorl (trimorous).
5. In the stem vascular bundles are collateral and open; they are few in number and arranged in a ring. Cambium is present between xylem and phloem and is responsible for the secondary growth in thickness.	5. In the stem vascular bundles are collateral and closed; they are many in number and are scattered in the ground tissue. Cambium is absent, so there is no secondary growth.
6. In the root xylem bundles are few (2-6) in number, rarely more. The cambium, though not present in the early stage of the development of the root soon makes its appearance as a secondary meristem and is responsible for the secondary growth of the root.	6. In the root xylem bundles are usually many in number. In monocotyledons roots cambium is absent and so there is no secondary growth.

THE ROOT

The root is that portion of the axis of the plant which grows downwards into the soil avoiding light and seeking moisture. It is not green in colour and does not develop leaves and buds. Under normal conditions the radicle develops into the root. It produces secondary branches which may again develop branches on them.

Root Cap—The root is protected at the tip by a cap-like structure; this is known as the *root cap*. It is thickest at the apex and gradually becomes thin at the sides. As the young root grows through the soil the tender apex of the root is liable to mechanical injury and drying out. The root cap protects the apex of the root from possible injury. The outer side of the root cap becomes more or less slimy and so the cap facilitates the passage of the root through the soil. On account of its continuous friction with the soil particles the root cap gets worn out, but it is continually renewed from within.

Root Hairs—Just a little behind the root cap a large number of minute hair-like structures develop on a limited space on the

surface of the root. These are the root hairs. In germinating seedlings of Wheat, Mustard, etc., grown in a moist chamber, they can be seen with the naked eye as fine short hairs on the surface of the root. They are simple in structure, each one being composed of a single cell. [Fig. 55].

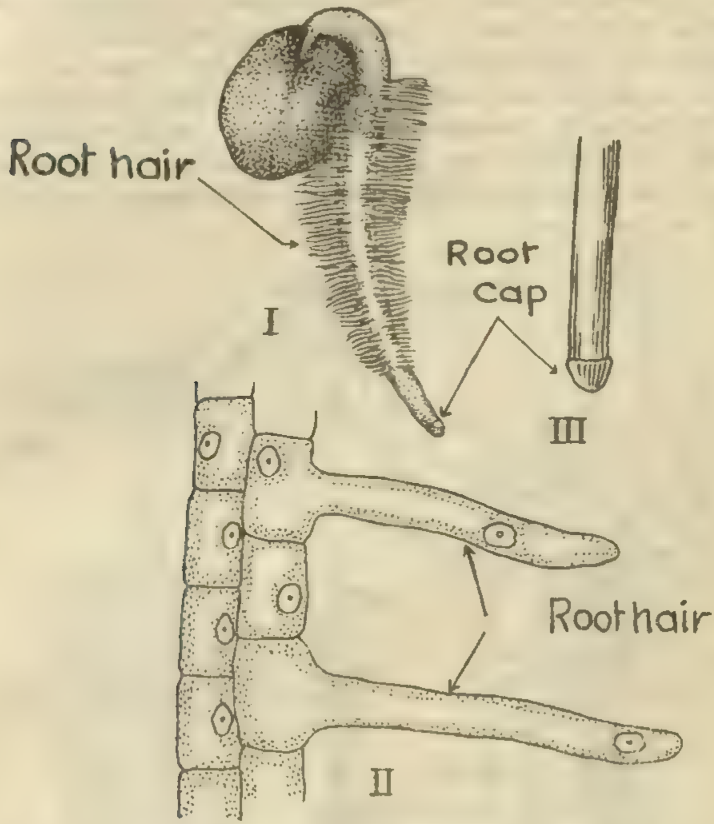


Fig. 55. I, germinating seedling of Mustard ; II, portion of a root showing unicellular root hairs, (much magnified) ; III, end of an aerial root of Banyan tree showing root cap.

The root absorbs water and raw food materials in solution from the soil. The absorbing function of the root is carried on principally by means of the root hairs and not by the entire surface of the root. The hairs also anchor the roots firmly in the soil.

The functioning life of root hairs is usually very short, often only a few days. As the root tip is growing in length, new hairs

are continually formed behind the growing apex while the hairs on the older parts die and turn brown.

The root hairs are very important plant structures. Plants are constantly supplied with water by their means. They come in very close contact with the particles of the soil and are so very delicate in nature that it is nearly impossible to remove a plant without destroying them. In the process of transplanting of seedlings, a large number of root hairs are destroyed, consequently the water supply becomes deficient. This is the reason for the wilting and withering of the seedlings for a day or two after transplantation. Therefore, at the time of transplanting a lump of soil should be taken up with the plant, in order that the root hairs may not be injured.

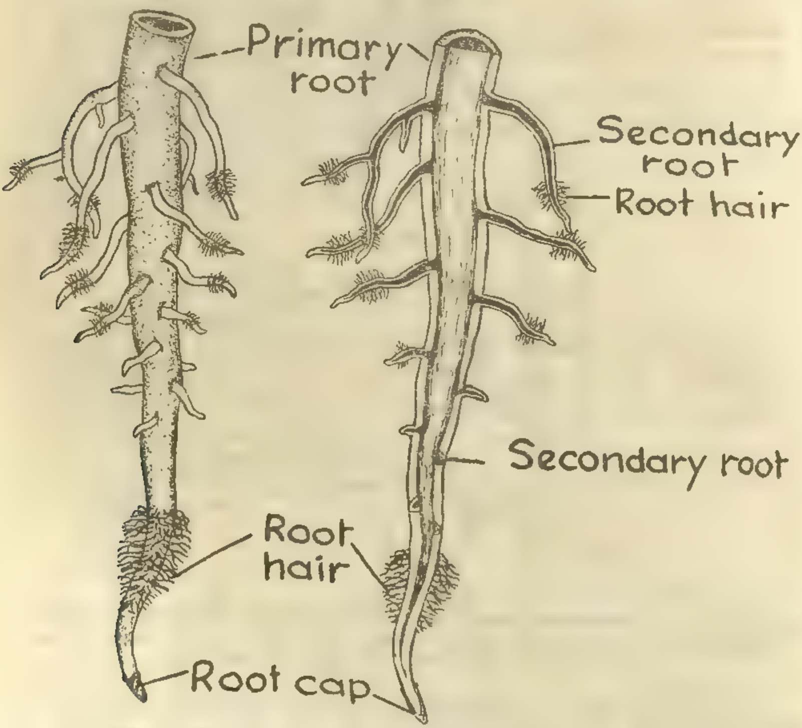


Fig. 56. left. Diagrammatic representation of a primary root showing the root cap, the root hairs and the secondary roots. Fig. 56 right. A longitudinal section of the primary root showing the endogenous origin of the secondary roots.

Kinds of roots—According to their mode of origin roots may be classified into *primary roots, secondary roots* and *adventitious roots.* The *primary root* of a plant is developed from

the radicle. It is the direct prolongation of the radicle downwards into the soil. The primary root is, therefore, the first root of the plant. In a large number of plants, particularly in the dicotyledons, it remains as the main root throughout the life of the plant.

The *secondary roots* (also known as *lateral roots*) are the branches of the primary root. Each branch, like the main root, develops root hairs behind its tip and is protected by a root cap (Fig. 56 left); and may produce branches in the same manner as does the primary root. By the continued formation of new branches together with the growth in length of roots already formed an extensive root system is developed in the soil.

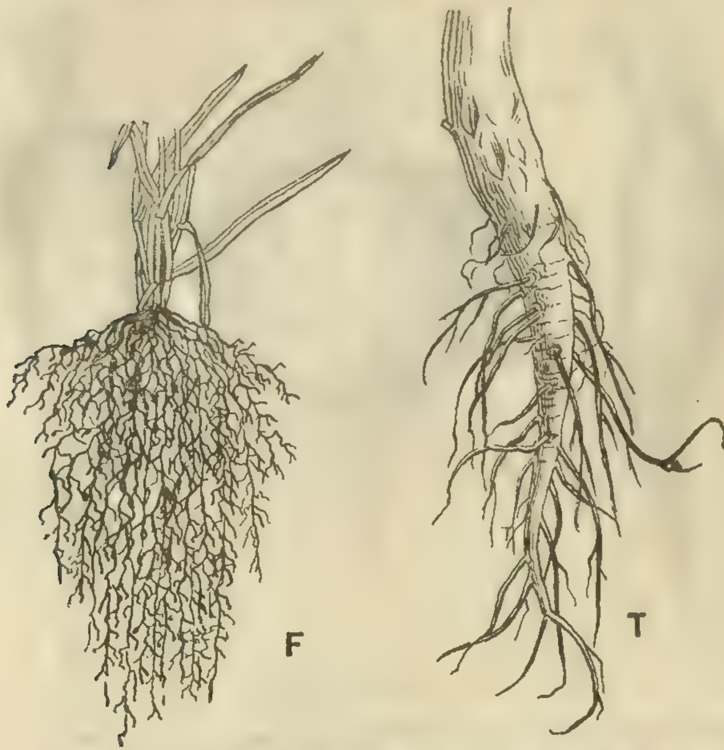


Fig. 57. F, fibrous root system in Paddy ; T, tap root system in *Amaranthus* (B. Nate sak).

The secondary roots do not arise as superficial outgrowths of the primary root, but develop from within it and are described as *endogenous* [Fig. 56 right].

Adventitious roots—All roots which do not develop from the primary root or its branches are *adventitious* roots. They may develop irregularly from any part of the stem, as in Sugarcane, Maize, Banyan, Marigold, etc., or may even arise from leaves, as in *Bryophyllum* (B. Patharkuchi) [Fig. 69A]. Most plants with trailing stems or with underground stems produce numerous adventitious roots on their stems. The adventitious roots are usually thin and fibrous, but sometimes they become thick and stout, as in Banyan, or may become fleshy and store food products, as in Sweet potato.

Root System—Two main types of root systems are recognised : tap-root system and fibrous root system. In the majority of

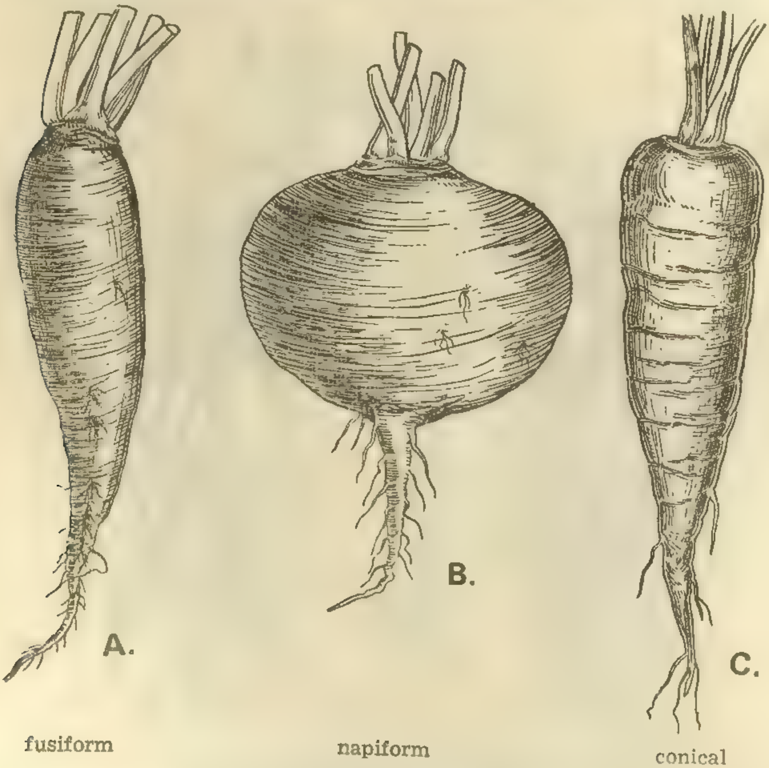


Fig. 58. Modifications of tap roots.

dicotyledons the primary root elongates and forms the root system of the plant. If the primary root is much thicker and stronger than its branches, it is called a *tap root*. Plants having roots of this type are described to have a *tap root system* [Fig. 57, T].

In many plants, particularly among the monocotyledons, the primary root does not become the main root of the plant, but ceases to grow when the plant is very young. In all such cases numerous thin and slender adventitious roots develop from the base of the stem. All these roots perform the function of fixing the plant

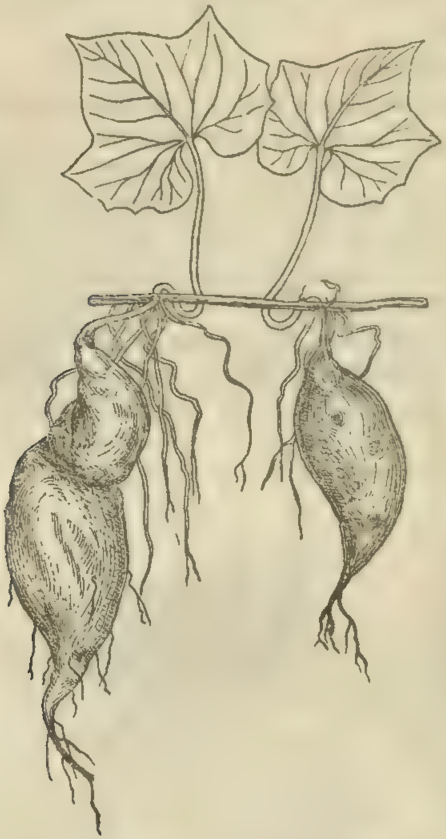


Fig. 59. Portion of a Sweet potato plant showing tuberous roots.

into the soil and of absorbing food and water from there. These are called *fibrous roots* and are found in Grass, Maize, Paddy, Wheat, Onion, etc. This type of root system is called *fibrous root system* [Fig. 57, F].

Functions of Roots

I. *Normal functions*—Roots penetrate the soil and fix the whole plant firmly in position. Another important function of

roots is to absorb water and raw food material in solution from the soil and pass them on to the leaves. For this purpose the root system of all plants is very nicely adapted.

II. *Special functions*—In addition to the normal functions roots perform a number of special functions. The structure of roots may be modified in relation to the special functions performed by them.

Modification of Roots

Roots as storehouses of food—Many plants store food in their roots. Such roots become much swollen and fleshy owing to the deposition of large quantities of food materials in them. The food is required for the future use of the plants. Such fleshy roots are known as *tuberous roots* or *root tubers*. They can be easily recognised as true roots by the presence of root caps, absence of leaves and by their internal structure.

Tap roots of certain plants become tuberous, as found in Carrot, Beet, etc. and according to their forms and shapes they are called by different descriptive names: (i) *conical*—when they are broadest above and gradually taper towards the lower end, as in Carrot; (ii) *fusiform*—When they are swollen in the middle and

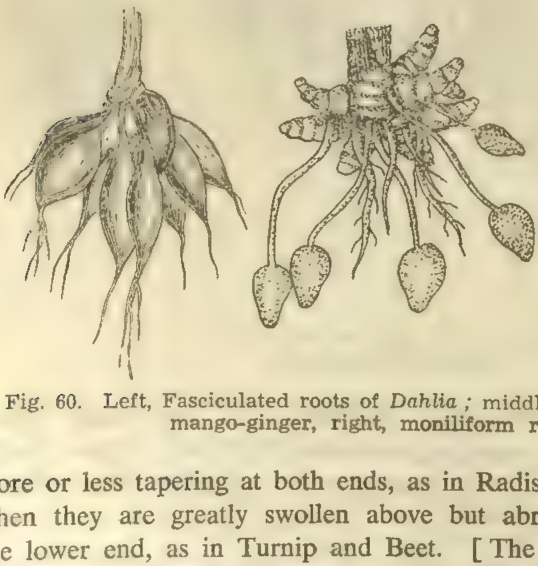


Fig. 60. Left, Fasciculated roots of *Dahlia*; middle, nodulose roots of mango-ginger, right, moniliform roots.

more or less tapering at both ends, as in Radish; (iii) *napiform*—when they are greatly swollen above but abruptly taper towards the lower end, as in Turnip and Beet. [The swollen tap root of Beet also includes the hypocotyl. In Radish and Turnip the swollen portion is entirely made up of the hypocotyl.] [Fig. 58].

Many adventitious roots may be used for the storage of food and thus become tuberous, as in Sweet potato [Fig. 69], *Dahlia*, *Asparagus*, many Orchids, etc. In *Dahlia* and *Asparagus* the root tubers arise in clusters from a common point and are often called *fasciculated*. [Fig. 60A].

When the root becomes suddenly swollen near its apex, it is called *nodulose*, as found in Mango-Ginger (B. Am-Ada) and in some Sedges. [Fig. 60B]. When in the root there are some swellings at frequent intervals, it is said to be *moniliform*, as in some grasses. [Fig. 60C].

Aerial roots

Roots of plants usually grow in the soil. But there are some plants which, for special purposes, produce peculiar adventitious

Fig. 61. Trunk of a Banyan tree with many prop roots.

roots which remain above the ground. These are called *aerial roots*. In some plants these aerial roots remain always in the air,

[illegible]

[illegible] [Fig. 61].

[illegible] stilt roots [Fig. 62].

[illegible] ing organs [Fig. 63].

Fig. 62. Stilt roots in Screw-pine

Fig. 63. Lower portion of a Maize plant showing the adventitious roots

Climbing roots—Climbing plants like Betel, *Scindapsus* (B. Gajpipul), climbing Aroids etc develop a number of adventitious roots from their stems. These roots attach the plants to their supports and thus help climbing.

[illegible]

Fig. [illegible]

deeper into the body of the host plant and absorb food from there; such roots are called haustoria (sing. haustorium) [illegible]

Aerial absorbing roots—In many Orchids and epiphytic Aroids (plants of the Arum family) special aerial roots are developed. These roots hang freely in the air and are specially adapted for the absorption of water from the surrounding air. Some of these roots also possess the green colouring matter (chlorophyll) and so can manufacture food [Fig. 65].

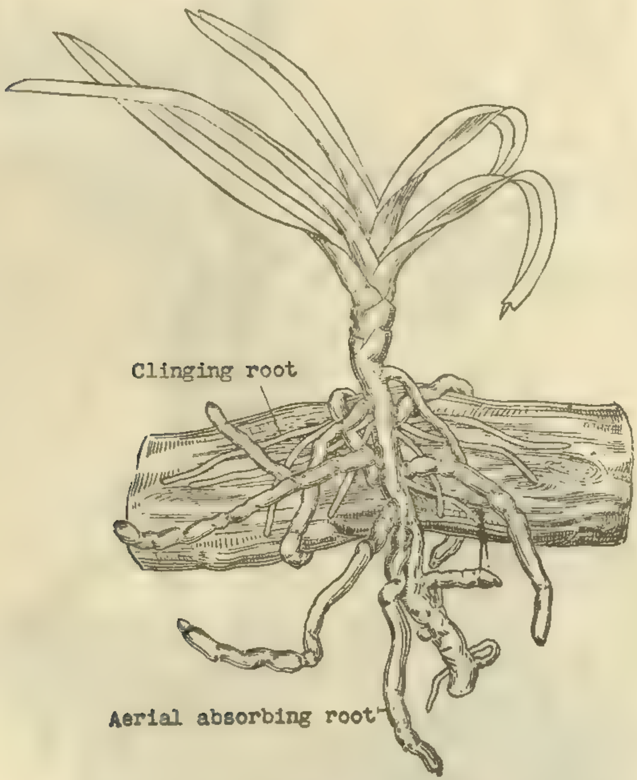


Fig. 65. Orchid plant, an epiphyte, showing aerial absorbing roots and clinging roots.

Breathing roots—Roots of certain plants growing in water-logged soil with little or no oxygen have difficulty in respiration. These roots send special erect aerial roots in the air which absorb oxygen through special pores developed on them and conduct it to the parts growing underneath the soil. Such roots are called *pneumatophores* or breathing roots and occur in plants like Sundri, Goria, Goran, etc. growing in the Sundribuns [Fig. 66].

Reproduction by means of Roots

Many plants reproduce by means of their roots. The fleshy roots like Sweet potato develop adventitious buds on them and may be useful in cultivation [Fig. 69B]. In *Trichosanthes dioica* (B. Patol) root-cuttings are used for the purpose of propagating the plants. Many other plants like Rose, Passion flower, etc. may also be propagated by means of roots.

Fig. 66. Pneumatophores or breathing roots (P) of *Kandelia* (B. Goria).

THE STEM

The Stem—The shoot is developed from the plumule of the embryo and consists of the stem and its branches and the leaves. The stem is thus the ascending axis of the plant which grows towards light and air. Usually it becomes green and is thus capable of manufacturing food products.

The region on the stem from which a leaf develops is called a *node* and the portion of the stem between two successive nodes is called an *internode* [Fig. 67]. The inner angle formed by the leaf-stalk with the stem or branch is called the *axil* of the leaf. A bud is usually found at the axil of the leaf. The apex of the stem is also occupied by a bud.

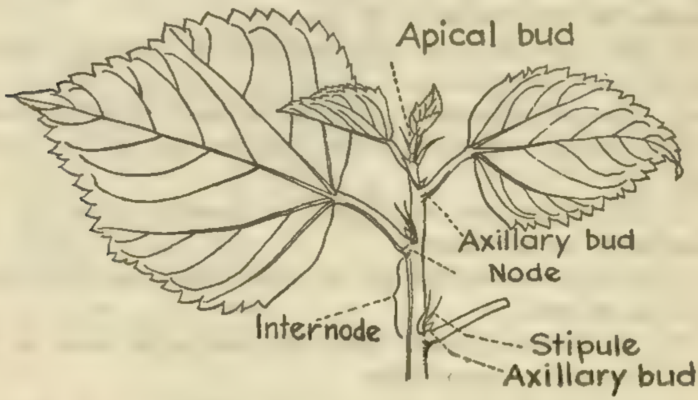


Fig. 67. Stem of China Rose showing nodes and internodes.

Distinction between the Root and the Stem

1. The root is the descending axis of the plant body whereas the stem is the ascending axis of the plant.

2. The root grows away from light into the soil, whereas the stem grows above the soil towards light.

3. The root is not normally green in colour, and cannot manufacture food ; whereas the stem is usually green in colour and can manufacture food.

4. The root has no nodes and internodes whereas these are always present in the stem.

5. The root can only bear branches, but the stem can develop branches, leaves and flowers. Branches of the stem arise only at the nodes in the axils of the leaves, whereas the root develops branches irregularly.

6. When the stem branches, the branch originates at surface of the main stem and near its extreme tip (Fig. 78) ; a branch root develops, not at the surface but from within a larger root and at some distance from the tip (Fig. 66, right). Stem branches are therefore described as *exogenous* and root branches, *endogenous*.

7. The apex of the root is protected by the root cap ; such a cap is absent in the stem-apex. The apex of the stem has a bud consisting of very small leaves.

8. The root bears hairs on its surface at a particular region ; such hairs are always unicellular. Hairs may develop from any part of the stem and may be unicellular or multicellular.

9. The internal structure of the root differs from that of the stem.

Functions of the Stem

1. The stem supports the branches and leaves and arranges them in such a manner that they can have the maximum amount of light and air.

2. The stem and the branches bear the flowers which are meant for the reproduction of the plant.

3. The stem also helps the conduction of raw food materials from the roots to the leaves.

4. The food prepared in the leaves is also conducted through the stem to the different growing regions and to the storage organs.

5. When the stem is young, it is normally green and can thus manufacture food matter.

6. Many stems, particularly the underground stems, act as the storehouse of food.

7. All the underground stems and some aerial stems are also used for vegetative reproduction.

THE BUD

The bud [Fig. 68] is a condensed rudimentary shoot consisting of a short axis in which the internodes are not elongated, so that the young leaves at the nodes are closely crowded together

overlapping the apex. The plumule of the embryo is the first bud of a plant.

According to their positions in the stem, buds are said to be *terminal* or *axillary*. The stem of a plant always ends in a bud; such a bud is called *apical* or *terminal bud*. The growth of the terminal bud results in the elongation of the stem. As the stem grows, the nodes become further apart owing to the growth in length of the internodes.

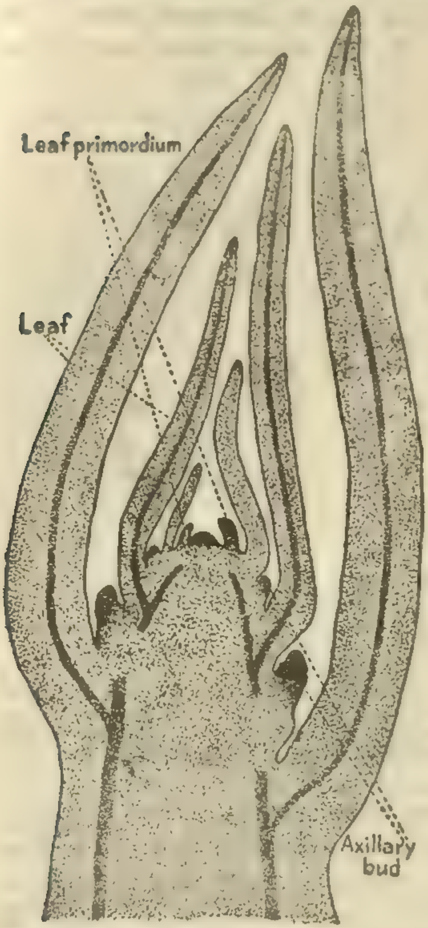


Fig. 68. Longitudinal section of an apical bud, showing young leaves, leaf primordia and axillary buds.

There are other buds which grow from the sides of the stem. They usually develop just above the leaf in the angle which the leaf makes with the stem, that is, in the axil; these are called *axillary* or *lateral buds*. An axillary bud may grow out into a branch.

If all the axillary buds had developed, there would have been a branch wherever there was a leaf. But a large number of these buds remain undeveloped. Such undeveloped buds are called *dormant buds*. Sometimes a dormant bud may "awaken" and form a branch; if the growing branch is cut off or injured, the dormant bud nearest to the cut or injured portion starts active growth, as is often seen after the prunning of branches.

Usually only one bud develops in the axil of a leaf; sometimes in addition to the normal axillary bud, one or more buds

develop in or near the leaf-axil ; all such additional buds are called *accessory buds,* as found in Rangoon Creeper, *Duranta,* etc.

When a bud arises from any other part of the plant except its normal position, that is, neither at the apex of a stem or branch, nor in the axil of the leaf ; it is said to be *adventitious.* The adventitious buds develop out of their normal order and without

Fig. 69. Adventitious buds developing from (A) the leaf of *Bryophyllum* and (B) the fleshy root of Sweet potato.

any definite relation to leaves. Adventitious buds may develop on the stems ; for example, when a trunk of a tree is cut down or broken, a large number of branches develop from the base of the shoot near the cut surface. These branches are produced mostly from adventitious buds and also from some dormant buds. Adventitious buds may be formed also upon roots, as in Sweet potato [Fig. 79B], *Dahlia,* Patal etc., and even upon leaves, as in *Bryophyllum* (B. Patharkuchi) [Fig. 69A].

A bud is said to be a *leaf bud,* when it grows out into a branch bearing ordinary leaves. All the buds just described are leaf buds. A *flower bud* is one which on opening gives rise to a flower only. As a fruit is produced from a flower, the flower bud

is called a *fruit bud* by the gardeners. With the production of a flower further growth in that direction does not take place.

In ordinary cases buds grow and develop into branches, but the axillary buds of some plants become swollen and fleshy owing to the deposition of food matters. When mature they fall down to the soil and develop into new plants. In this way they help vegetative reproduction. Such modified buds are known as *bulbils*, as in Yams (Beng. Kham alu or Chupri alu) [Fig. 70].

Fig. 70. Bulbil in the axil of a leaf of Yam.

Protection of bud—Buds are ordinarily protected by the bases of leaves, but in some cases special structures are developed to protect the buds. Thus they may be protected by means of modified leaves called *bud scales*. Buds so protected are called *scaly buds*, as found in Bamboo, Jack-fruit, Banyan, etc.; buds without scales are called *naked buds*. Most plants of the tropical countries and all herbaceous plants have naked buds. Bud scales or the outer leaves of naked buds may be covered with a dense coating of hairs or with waxy or resinous secretions. All these coverings afford protection to the buds from possible mechanical injury.

In cold climates buds formed at the end of the year do not develop at once, but remain dormant during the winter. Such buds often attain a considerable size and are protected by several layers of bud scales. These large scaly buds resume their development next spring.

Branching—Branches are similar members developed on stems. They resemble the stem in their structure, development and function. The mode of arrangement of branches on the stem is known as *branching*.

In flowering plants the axillary buds give rise to lateral branches and upon the latter, branches are developed in a similar manner; and under normal circumstances all the branches develop in this way. This method of branching is known as *lateral branching*. The main stem of a plant is called the primary axis, the branches upon it secondary axes, those borne by the latter tertiary axes, and so on.

Lateral branching may be *racemose* and *cymose*. In the racemose type of branching the primary axis continues to grow indefinitely producing lateral branches in an acropetal succession, that is, from the base upwards. The branches thus developed are always smaller than the main stem. In this case a true axis or monopodium (*mono*—one, *podium*—a foot or a base on which the branches are set) can be followed throughout the entire

branch system and therefore the method of branching is also called *monopodial*, as in Pine, *Polyalthia* (B. Devdaru), *Casuarina* (B. Jhau), etc.

In the *cymose* type of branching the growth of the apical buds of the primary axis is soon checked and so it ceases to elongate; then one or two of the lateral branches soon equal or exceed the main stem in vigour; these branches in their turn cease to grow and are overtopped by the branches they bear. This method of branching is found in many trees and shrubs.

There is another type of branching which is found only among Cryptogams or non-flowering plants. In this case the apical bud of the stem divides directly into two equal parts producing two branches of equal size and the branches in their turn divide in the same manner. The method of branching is termed *dichotomy* or *dichotomous branching*. Figure 71 shows the dichotomous branching of *Lycopodium*, a non-flowering plant.

Herbs, Shrubs and Trees—Plants are classified into herbs, shrubs and trees according to the size and succulence or woody nature of their stems. *Herbs* are small plants whose stems are usually soft and succulent, e.g., Potato, Paddy, Mustard, Radish, etc. *Shrubs*—Woody plants which branch profusely from the base

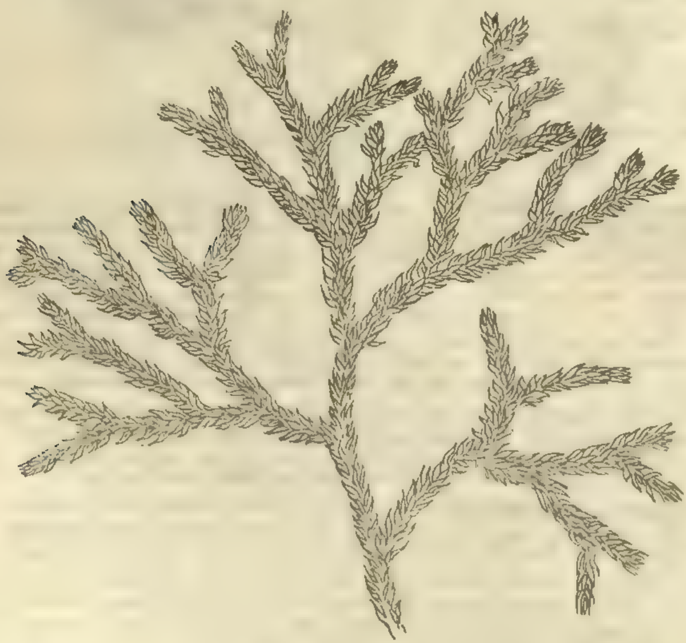


Fig. 71. Stem of *Lycopodium* showing dichotomous branching.

and do not have any distinct trunk, are called shrubs, e.g., China Rose (B. Jaba), Lemon (B. Pati Lebu), Pomegranate, etc. *Trees*—Woody plants which are tall and have distinct trunks are called trees, *e.g.*, Mango, Banyan, Coconut, Palmyra-palm, etc.

Duration of Stems—Plants are regarded as *annual, biennial* and *perennial* according to the number of years they live. *Annual plants* are those which live only for one growing season, e.g., Paddy, Wheat, Mustard, Jute, etc. *Biennial plants* live for two years or seasons. In the first year they produce only leaves and in the second year flowers, fruits and seeds. Radish, Turnip and Beet are biennials in cold countries, but they behave as annuals in tropical countries. *Perennial plants* are those which live for more than two years. Most of the herbaceous plants are either annual or biennial, while only a few are perennial. Banana plant is a perennial herb. All the shrubs and trees are perennial.

FORMS OF STEMS

Stems may be *erect* or *weak*. The stems of most plants are erect, that is, they are sufficiently strong to stand in an upright position.

Erect stems may be of the following kinds: (1) *Excurrent*—The stem is said to be excurrent when the main axis goes on elongating giving off branches from its sides and on account of this method of branching the shoot assumes cone-shaped or pyramidal appearance. The branching is racemose in this case, e.g., *Polyalthia* (B. Debdaru), Pine, *Casuarina* (B. Jhau), etc. (2) *Deliquescent*—The stem is called deliquescent when the growth of the main axis is checked after it has grown for some distance above the ground and it is divided into a number of branches, which in their turn branch again and again; as a result of such branching the plant becomes domeshaped in appearance, e.g., Banyan, Jack-fruit, Mango, etc. (3) *Caudex*—The stem is said to be caudex when it is unbranched and bears a number of large leaves at its top, e.g., Palms, etc. (4) *Culm*—The peculiar closely jointed stems of Maize, Sugarcane, etc. go by the name of culm.

Weak-stemmed plants are not mechanically strong enough to stand erect. Such plants usually trail upon the ground or climb upon other erect plants or supports. The former are known as *trailers* and the latter, *climbers*.

When the trailers or trailing stems run along the ground, but do not root at the nodes, they are said to be *procumbent*, e.g., *Basella* (B. Puin). More usually the trailing stems grow horizontally on the surface of ground and develop roots at the

Fig. 72. A, Runner of *Hydrocotyle* ; B, Offset of *Pistia*.

nodes ; these are known as *creeping*, e.g., Sweet potato, Dub grass, etc.

There are some creeping horizontal stems which are especially modified for the purpose of vegetative reproduction. There are two main types of such stems :

(i) *Runner or Stolon*—The runner is an elongated slender branch of the main stem. It originates from the axil of a lower leaf of the main shoot which is of the rosette type and runs more or less horizontally on the surface of the soil. It has long internodes and develops new shoots, that is roots, leaves and flowers

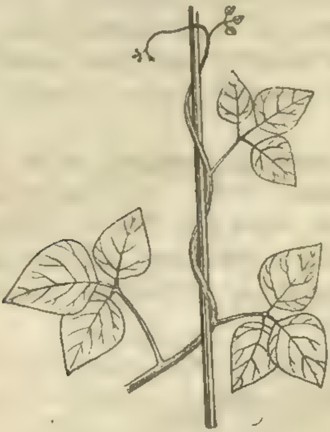


Fig. 73A. Twining stem of Bean.

Fig. 73B. Portion of a Gourd plant, a tendril climber.

at all or some of the nodes. By the death of the runners the shoots at the nodes become established as independent plants, e.g., *Hydrocotyle* (B. Thankuni) [Fig. 82A], *Oxalis* (B. Amrul), Strawberry, etc.

(ii) *Offset*—The offset is a short, prostrate and more or less thickened branch which takes its origin from a bud in the axil of the lower leaf of the main shoot (which is of the rosette type). It produces a rosette of leaves and a tuft of roots at its end ; when detached from the mother plant it forms an independent plant which is capable of producing other offsets in a like manner. It may be regarded as a modified runner, e.g., *Pistia* (B. Topapana) [Fig. 72B], Water hyacinth (B. Kachuripana).

Climbing plants have very weak stems which are not strong enough to remain erect and bear the weight of their branches and leaves. They climb on other plants or supports either by twining round them, or with the help of special structures developed in them. Climbing plants are also known as *lianas*. They may be classified into the following types:

1. *Twiners or Stem-climbers* [Fig. 73A]—These have long slender stems by means of which they twine round their supports. Possibly the twiners are the most specialised climbers. Examples, *Clitoria* (B. Aparajita), Bean, *Quamoclit* (B. Tarulata).

2. *Tendril-climbers* [Figs. 73B, 79I]—They are special climbers which climb on other plants or supports with the help of specialised organs called *tendrils*. The tendrils are thin thread-like leafless unbranched or branched structures which may be the modifications of stems or branches, leaves, stipules and floral axes.

Tendrils may be modified stems or branches, as in *Vitis* (B. Goale lata), Grape vine, Passion flower, etc.; leaves as in *Lathyrus aphaca* (B. Jangli matar), Sweet pea, Pea, etc.; stipules, as in *Smilax* (B. Kumarika); modified floral axes or floral stalks, as in *Cardiospermum* (B. Lata fatki) and *Antigonon*, a common garden climber.

The tendrils of plants of the Gourd family are not all of the same type. They may be modified branches or leaves in different plants.

3. *Root-climbers*—These plants climb on their supports with the help of adventitious roots developed from the stem. The roots clasp the trunk of a tree or any other support, or penetrate into the furrows of the bark of the supporting tree. *Examples, Betal, Scindapsus* (B. Gajpipul), etc.

4. *Hook-climbers or Scramblers*—These are plants which climb on their supports by means of prickles, e.g., climbing rose, or by thorns, e.g., Glory of the garden (B. Baganbilas), or by curved hooks, e.g., *Artabotrys* (B. Kantali champa).

MODIFICATIONS OF STEMS

Normally stems are cylindrical structures which grow more or less above the ground. But some of them are variously modified and can hardly be recognised as stems. Their nature can, however, be known after careful study.

Underground Modification of Stems

These are modified stems which grow beneath the surface of the soil. Because of their underground position these stems are often mistaken for roots, but can be easily distinguished from them by the following characteristics : (1) they have nodes and internodes ; (2) scale leaves develop at the nodes and in the axils of the scale leaves buds are produced ; (3) the underground stem has an apical bud from which an aerial shoot is given off ; (4) the internal structure of an underground stem resembles that of a stem and not that of a root.

Like the roots they are not green in colour. Usually they are fleshy and store abundant food for the future use of the plant. They are meant for vegetative multiplication.

There are four main types of underground stems, viz., *rhizome, tuber, bulb* and *corm.*

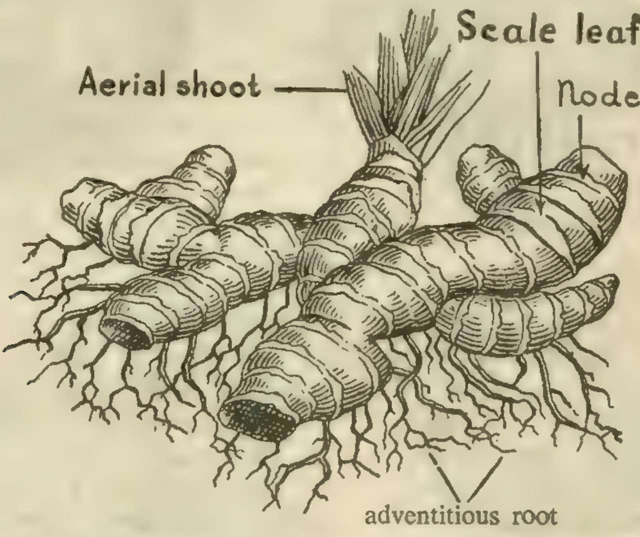


Fig. 74. Underground stem (rhizome) of Ginger.

Rhizome or Root-stock [Fig. 74]—It is an elongated thick and fleshy stem of variable length growing horizontally underneath the surface of the soil. It has distinct nodes and internodes ; at the nodes it bears scaly leaves in the axils of which buds are produced. The rhizome develops a large number of adventitious roots on its undersurface and one or more leafy shoots above. Examples, Ginger, Turmeric, Canna, etc. Occasionally the rhizome is short and may grow more or less vertically with its top

growing buds, partially above the ground, as in Alocasia (B. Mankachu).

At the end of the growing season the aerial shoots with their foliage leaves die down, but the rhizome remains alive in a dormant condition. In the next growing season some of the buds develop into aerial leafy shoots, while by the growth of apical buds the growth of the rhizome is continued. A rhizome usually dies off each season at one end and grows at the other.

Tuber (Fig. 75).—A tuber is a short, swollen and fleshy underground stem. It usually develops at the end of a subterranean branch of the main stem, and is recognizable by the presence of 'eyes' [illegible]. The most common example of a tuber is the Potato. It bears on its surface a number of 'eyes' arranged in spiral manner. Each 'eye' is a bud in the axil of a minute scale leaf and is capable of developing into a shoot.

Fig. 75. Top figure, lower portion of a potato plant showing many tubers in different stages of development. Bottom figure, a potato tuber; S, scar where the underground branch was attached.

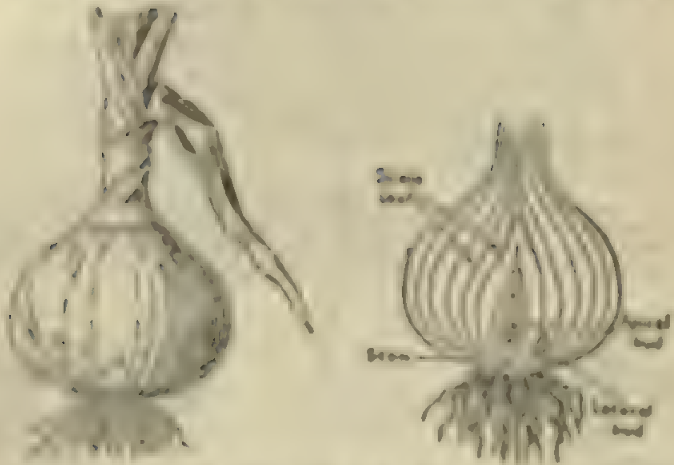
The tuber is at first very small, but grows rapidly and becomes filled up with food materials. When very young the tuber is seen to bear minute scale leaves with small buds (eyes) in their axils; they do not grow with the growth of the tuber and fall off early. In a full-grown potato the scars of these scale leaves only are left. At the apex of the tuber, also known as the rose end, the scale leaves follow one another more closely and so the eyes are more crowded there than at the other end.

It is interesting to note that a potato has three kinds of stems — (1) aerial stems bearing green leaves and flowers; (2) underground branches of the main stem (stolons) bearing scale leaves; and (3) the tubers which usually develop at the end of these underground branches.

Tubers (also called stem-tubers) should be carefully distinguished from root-tubers (also known as tuberous roots). The root-tubers are fleshy

[illegible]

Bulb (Fig. [illegible]).—A bulb is an underground stem in which the stem is reduced to a very short flattened disc. The whole



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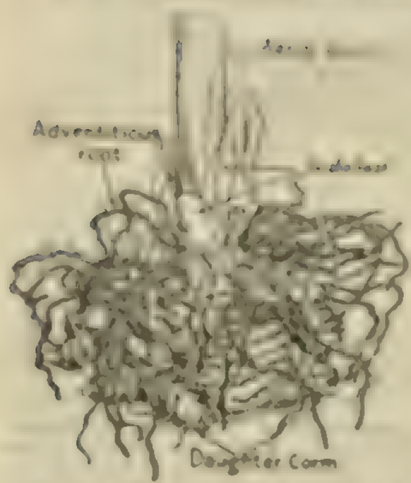


[illegible]

structure is completely enveloped by many scale leaves overlapping one another. The scale leaves are fleshy and are developed from the upper surface of the disc, while from its lower surface a cluster of fibrous roots develop. Examples: Onion, Garlic, Garden Lily, etc.

The fleshy scale leaves of the bulb are surrounded by a number of dry brownish papery scales. The fleshy scales store food which is utilised for the production of aerial shoots.

Corm [Fig. 77]—A corm is a large thick, vertical underground stem, more or less rounded in shape. It may be regarded as a much condensed rhizome. Over its solid body are scattered a number of membranous scaly leaves, from the axils of which at some places develop buds in the form of daughter corms. A large number of adventitious root are borne all over the body of the corm. Example, *Amorphophallus* (B. Ol).

In the resting condition or when it is young, the apical bud of the corm is enclosed by a few sheathing scale leaves. In the spring the first leaf of the aerial shoot comes out piercing through the scale leaves, which may also grow for a short time, but ultimately shrivels up.

The corms of *Crocus* and *Gladiolus* of gardens are also known as solid bulbs and are different from the corm of *Amorphophallus* (B. Ol), which is really a much condensed rhizome. The rhizome nature of the corm of *Amorphophallus* can be observed by close examination of a young corm

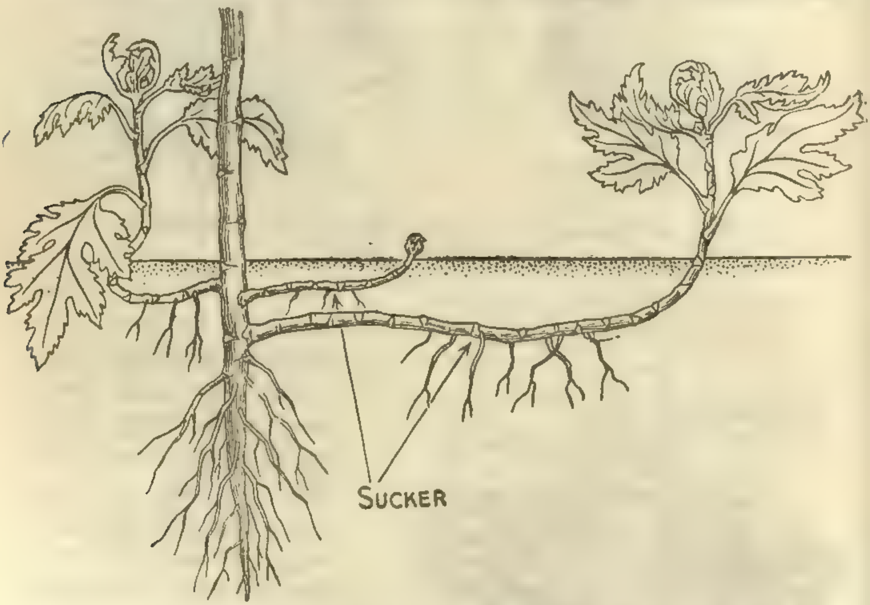


Fig. 78. Lower portion of *Chrysanthemum* (B. Chandramallika) plant with three suckers. Note that the suckers develop nodes and internodes and scale leaves at the nodes.

or a daughter corm. The underground stem of *Polyanthes* (B. Rajanigandha) may be described as a solid bulb, as in this case the axis of the stem becomes a large mass instead of remaining small as in the bulb. Its scale leaves also are small and scattered over the surface of the solid stem.

The *sucker* [Fig. 78] is an underground stem which can be easily distinguished from the above types. It is not fleshy

since it does not store food products. It mainly serve the purpose of vegetative reproduction. It arises as a branch from the underground portion of the stem, and after running horizontally

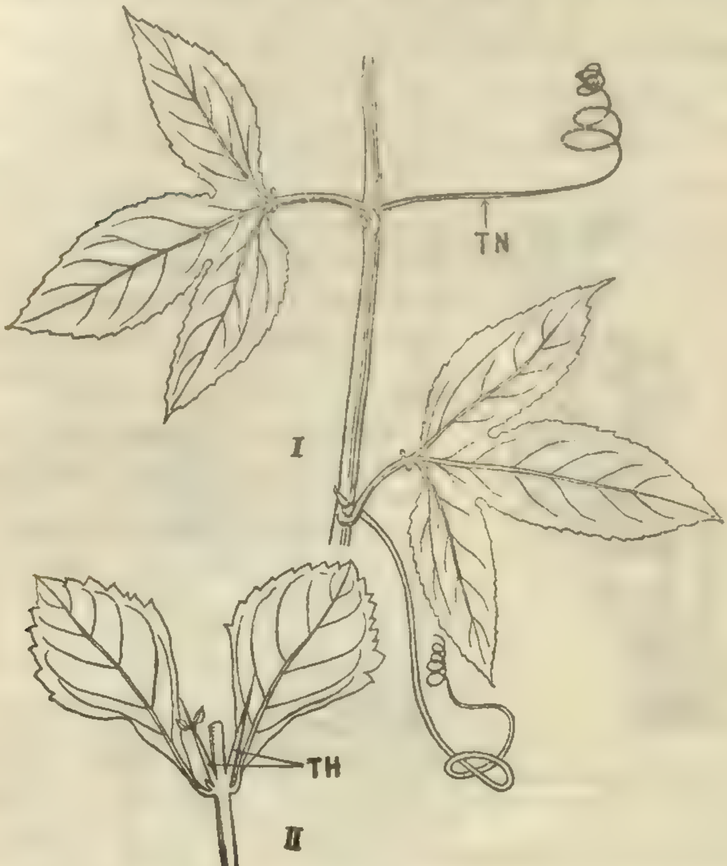


Fig. 79. I, Tendril of Passion flower ; II, Thorn of *Duranta ;* one of the thorns has developed a pair of leaves.

for some distance under the soil and giving off roots as the nodes, it turns upwards in the air, and ultimately forms an independent plant, e.g., *Chrysanthemum* (B. Chandramallika), *Mint* (B. Pudina).

Aerial Modifications of Stems

Thorn [Fig. 79, II]—The thorn is a hard, woody and pointed structure developing in the axil of a leaf. It is a suppressed and

undeveloped branch and usually acts as a defensive weapon, as found in *Duranta*, Glory of the garden (B. Bagan bilas), Wood-apple (B. Bel). In some cases the thorn may bear leaves or flowers, and may occasionally become branched. The stem nature of thorns can be proved by their axillary position and by their occasional production of leaves and flowers.

Stem-tendril [Fig. 79, I]—It is a long filamentous, spirally coiled body which can twine round a support and thus help a weak plant to climb. It is peculiarly sensitive to contact, as in Passion flower (B. Jhumka lata), Vitis (B. Goale lata), etc. That they are really modified stems, or branches can be recognised by their position. Stem-tendrils should be carefully distinguished from leaf-tendrils which are modifications of leaves.

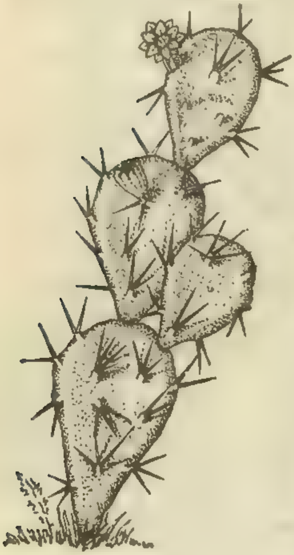


Fig. 80. Phylloclade of *Opuntia* (B. Phanimanasa).

Phylloclade or Cladode [Fig. 80] —In some plants where leaves are poorly developed or do not develop at all, the stems become flat, leaf-like and green in colour. Such stems are known as *phylloclades* ; they perform the functions of leaves. A phylloclade can be distinguished from a leaf by the following characteristics : (i) it has nodes and internodes ; (ii) it may develop upon is minute leaves ; (iii) it often develops branches and may bear flowers. Examples, *Opuntia* (B. Phanimanasa), *Asparagus* (B. Satamuli), *Cactus*, *Lemna* (B. Khudi pana), etc.

THE LEAF

The leaf is a thin expanded and flattened organ of the plant which differs from the stem in its structure and organisation. It always arises at a node as a lateral outgrowth and bears a bud in its axil. Normally it is green in colour. The ordinary green leaf of a plant is also called a *foliage leaf*.

The leaf develops at the growing point of the stem as a small lateral swelling which at first shows no differentiation. This is called the *leaf primordium* (see Fig. 68). As growth proceeds

the leaf primordium is differentiated into the normal structure of a leaf.

Functions of the leaf—The leaf is the most important of all the vegetative organs. It performs many useful physiological functions for which its structure is specially adapted. It has many small openings, called stomata, particularly on its under surface through which exchange of gases takes place between the external air and the inner part of the plant body in connection with the processes of respiration and manufacture of food products.

1. *Manufacture of food*—The most important function of the leaf is to manufacture food material. The chloroplasts (containing the green colouring matter, chlorophyll) of leaves absorb

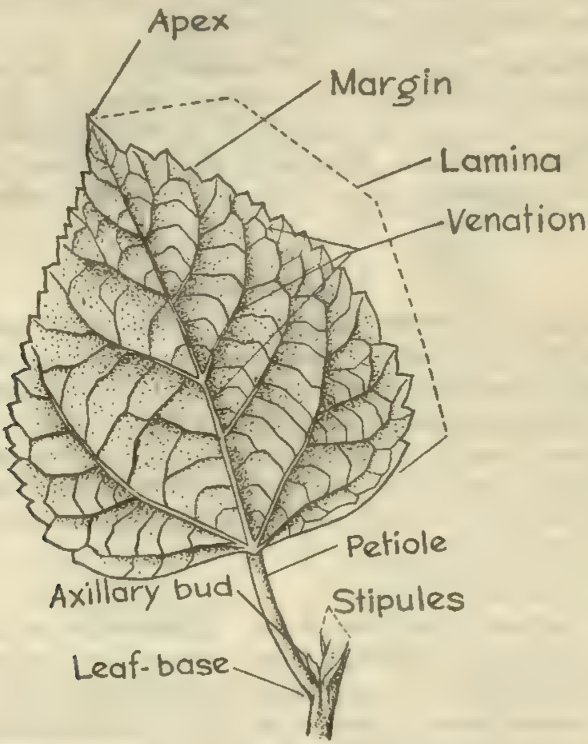


Fig. 81. Leaf of China Rose showing different parts.

carbon dioxide from the atmosphere and manufacture sugar and starch from the absorbed gas and the water present in the leaves. The whole process takes place only in the presence of sunlight.

2. *Respiration*—Leaves take in oxygen and give out an almost equal volume of carbon dioxide in connection with the process of respiration.

3. *Transpiration or Evaporation of Water*—The water absorbed by roots is sent up in the leaves; much of the water thus sent up is not required and the excess water is given out from the leaves in the form of vapour mainly through the stomata.

4. *Protection of axillary buds*—Leaves protect the buds situated in their axils.

5. *Food storage*—Fleshy leaves of certain plants store food and water for the future use of plants.

6. *Vegetative reproduction*—Leaves of *Bryophyllum* (B. Patharkuchi) and some other plants develop adventitious buds on them from which new plants can grow.

Parts of a leaf—A foliage leaf consists of three distinct parts: (i) *Leaf-base*—the base of the leaf by means of which it is attached to the stem. (ii) *Leaf-stalk* or *Petiole*—the stalk of the leaf which connects the blade of the leaf with its base. (iii) *Leaf-blade* or *Lamina*—the green expanded flattened portion of the leaf.

LEAF-BASE

It is usually not very prominently developed. In plants like Pea, Sensitive plant, Bean, *Cassia* and many other plants of the Pea family the leaf-base is swollen and is more or less cushion-like. Such a leaf-base is called *pulvinus.* In some cases the leaf-base becomes more or less enlarged and clasps the stem completely or partially. Such bases are called *sheathing leaf-bases,* as found in Coriander, Coconut, Palmyra palm, Betel-nut tree, Banana, Grasses [Fig. 83, II].

Stipules [Fig. 82]

The leaf-base often bears a pair of outgrowths at its base; these are called the *stipules.* When stipules are present in a leaf, the leaf is said to be *stipulate,* e.g., China Rose, Rose, Jute, etc. and when they are absent, it is said to be *exstipulate,* e.g., Mango, Custard Apple, Litchi, Guava, etc. Stipules may be of the following kinds:

(1) *Free lateral*—when the stipules, which are small and green, develop on the two sides of the leaf-base and remain free from each other, as in China Rose [Fig. 81], Cotton, etc.

(2) *Adnate*—when the two stipules unite with the petiole which becomes more or less winged in appearance, e.g., Rose [Fig. 82, I].

(3) *Interpetiolar*—These stipules are found in *Ixora* (B. Rangan), *Anthocephalus* (B. Kadamba), etc. In these plants the leaves are opposite and the stipules lie between the petioles of the opposite leaves [Fig. 82, II].

Fig. 82. Different kinds of stipules. S, stipule, I, Adnate stipule of Rose ; II, Interpetiolar stipule of *Ixora* (B. Rangan) ; III, Ochreate stipule of *Polygonum* (B. Panmarich) ; IV, Foliaceous stipule of Pea ; V. Tendrillar stipule of *Smilax* ; VI, Spinous stipule of Indian Plum (B. Kul) ; VII, Bud scale of Jack.

(4) *Ochreate*—when the stipules form a hollow tube and enclose the internode up to a certain distance above the insertion of the leaf, as in *Polygonum* (B. Panmarich), [Fig. 82, III], *Rumex* (B. Ban palang).

(5) *Bud scales*—These stipules are more or less scale-like in appearance. They cover the young apical shoot and the axillary bud and fall off when the leaves of the shoot begin to grow, as in Banyan, Jack [Fig. 82, VII], etc.

Modifications of stipules—The stipules are often modified in order to perform special functions, in addition to their normal function of protecting the axillary buds.

(i) *Foliaceous*—when the stipules become large and leaf-like as in Pea. In *Lathyrus* (B. Jangli-matar) the leaves are modified into tendrils and the work of the leaves is entirely taken up by the foliaceous stipules [Fig. 82, IX].

(ii) *Tendrillar*—when the stipules are modified into tendrils and thus help the plant to climb upon other plants or supports, as in *Smilax* (B. Kumarika) [Fig. 82, V].

(iii) *Spinous*—when the stipules are modified into spines (sharp woody and pointed structures) which act as defensive weapons against the attack of animals, an in *Acacia* (B. Babla), Indian plum (B. Kul) [Fig. 82, VI], etc.

LEAF-STALK or PETIOLE

The petiole holds the blade in favourable position with respect to light. It also conducts water and raw food material from the stem to the leaf-blade and prepared food formed in the blade to the stem.

A leaf having a petiole is said to be *petiolate*, e.g., Mango, Custard apple, China Rose, etc., and a leaf which has no petiole is called *sessile*, e.g., *Calotropis* (B. Akanda). The petiole is usually stem-like or cylindrical in structure, but may become flat or grooved on the upper surface. In many aquatic plants the petiole may be more or less swollen and spongy, as in Water hyacinth. In some cases the petiole develops two wing-like expansions on its two sides and is then said to be *winged*, as in Lemon, Shaddock (B. Batabi nebu) [Fig. 83, I]. In certain Australian Acacias (plants of the Babla family) the leaf-blade does not develop at all or fall off very early, and so the petiole becomes expanded and leaf-like in form. Such a modified petiole is called *phyllode*; it performs all the functions of the leaf-blade [Fig. 83A].

The petiole and the blade usually remain in the same plane, but in some plants the petiole is attached near about the middle

on the under surface of the lamina. Such a leaf is called *peltate*, as in Lotus, Garden Nasturtium, etc. [Fig. 83, III].

Ligule [Fig. 83, II]—In grasses the petiole is represented by a complete sheath enclosed round the stem, and at the point

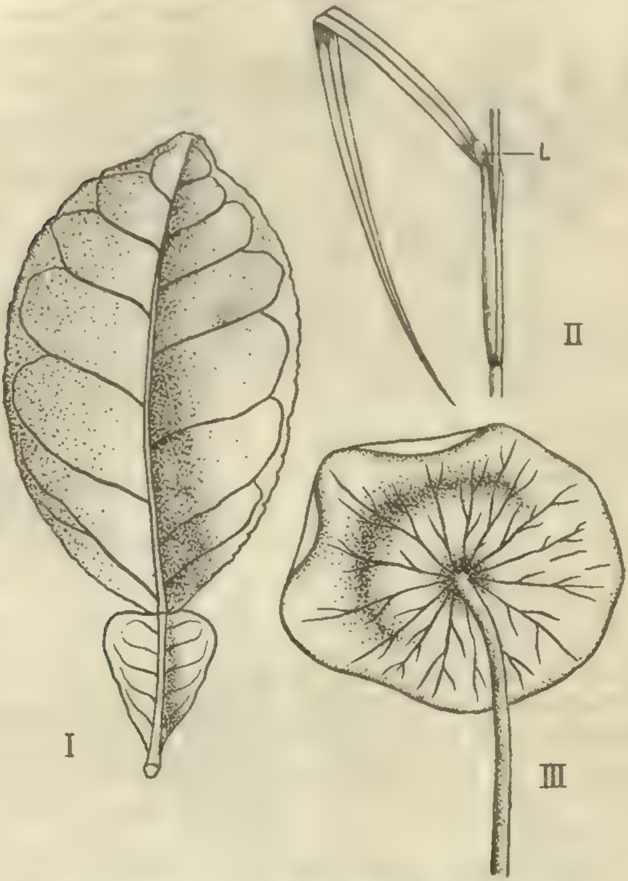


Fig. 83. I, Leaf of Shaddock (B. Batabi nebu) showing winged petiole, II, Leaf of grass showing ligule (L). III, Peltate leaf of Lotus.

where the leaf-blade bends away from the sheath there is a membranous scale-like or hairy outgrowth. This scaly or hairy outgrowth is called the *ligule*. A leaf having a ligule is called *ligulate*.

LEAF-BLADE or LAMINA

The lamina is the most important part of the leaf. Its thin and expanded form is most suited to perform all the essential functions of the leaf.

The form or outline, margin, apex and venation of the leaves are usually different in different kinds of leaves.

Venation [Fig. 84]

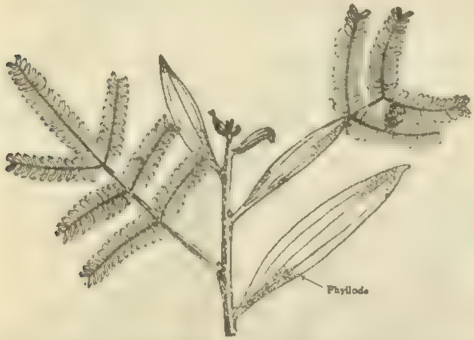


Fig. 83A. Phyllode of *Acacia melanoxylon*. The figure has been drawn from a specimen collected from the Botanic Gardens, Darjeeling.

The thread-like structures or nerves which arise from the end of the petiole and branch repeatedly traversing through the lamina in various directions, are called veins. The way in which the veins are arranged in the lamina is called *venation*.

There are two principal types of venation, viz., *reticulate* or *net venation* and *parallel venation*.

Reticulate venation—The venation is reticulate when the veins branch again and again forming a complicated network through the leaf. The net veined leaves may be (i) *unicostate* or *pinnate* and (ii) *multicostate* or *palmate*. In the *pinnate* type there is a principal vein called the midrib which passes through the middle of the leaf. From the midrib branches develop on both sides, which in their turn also give rise to branches in a reticulate manner, as in Mango (Fig. 84 D), Guava, Jack, etc. In the *palmate* or *multicostate* types a few large veins arise at a common point at the tip of the petiole and radiate in different directions or meet at the apex of the leaf. When the large veins proceed upwards and diverge towards the margin, the venation is called *multicostate divergent*, as in Gourd, (Fig. 48 E) Papaw, China Rose, Castor, etc. When the strong veins do not radiate in different directions, but meet or tend to meet at the apex, the venation is called *multicostate convergent*, as in Indian palm, *Smilax* (B. Kumarika), *Bay leaf* (B. Tejpata) [Fig. 84 F], *Dioscorea* (B. Kham alu or Chupri alu).

Parallel venation—The venation is parallel when the veins run approximately parallel to one another. When a parallel-veined leaf is carefully examined it is observed that small veinlets connect the parallel veins, and run at right angles to them. Parallel venation may be : (i) *pinnate* or *unicostate*—When there is a strong midrib

running through the middle of the leaf from which the smaller veins, run more or less parallel to one another towards the margin, as in Banana [Fig. 84 G], Canna ; and (ii) *palmate* or *multicostate*—when the veins all run approximately parallel to one

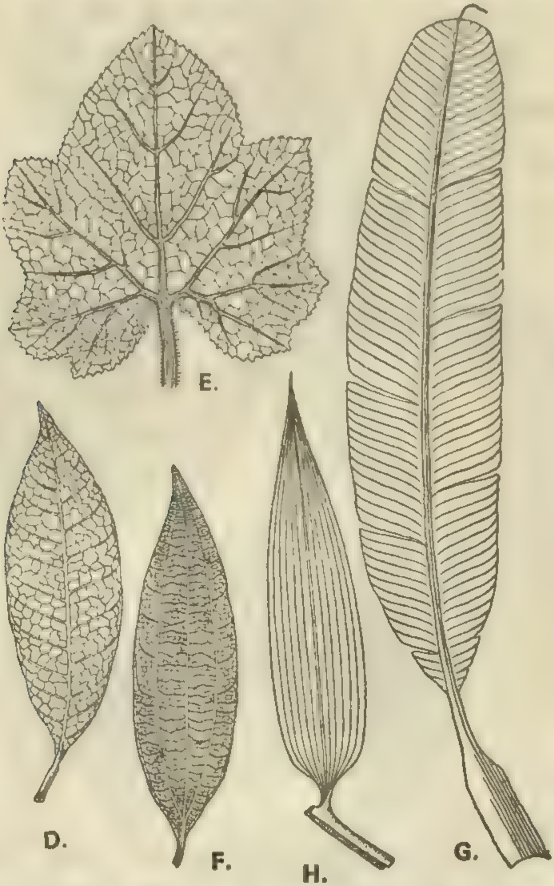


Fig. 84. Types of Venation. D, E, F,—reticulate venation ; D, Mango leaf—unicostate ; E, Gourd leaf—multicostate divergent ; F, *Bay leaf* (B. Tejpata)—multicostate convergent ; G, H,—parallel venation ; G, Banana leaf—unicostate ; H, Bamboo leaf—multicostate.

another from the base to the apex of the leaf, as Grasses, Bamboo [Fig. 84 H].

Reticulate venation is characteristic of dicotyledons and parallel venation of monocotyledons. But there are certain exceptions to this. Arum, *Smilax* and *Dioscorea* (B. Chupri alu or Kham alu)

are monocotyledons but have net-veined leaves; *Calophyllum* (B. Sultan champa), a dicotyledon has parallel venation.

Function of veins—Veins are made up mainly of the conducting or vascular tissues that run continuously with the petiole. So the veins are concerned in the conduction of water and raw food materials throughout the different parts of the leaf and also in the distribution of the food from the leaves to the different parts of the plant. The veins form the skeleton of the lamina and thus give sufficient mechanical support to it.

Incisions of the Leaf

We have learnt that the leaf-blade may be entire or more less toothed. In certain plants, however, the lamina may be deeply incised or indented at its margin. As a result of the deep incisions the leaf-blade is divided into a number of parts called *lobes* and the leaf is said to be *lobed.* Accordingly as they are pinnately or palmately veined, leaves may be pinnately lobed [Fig. 85 I], e.g., Maxican poppy (B. Shealkanta), Marigold, Radish, or palmately lobed [Fig. 85, II], as in Cotton, Castor oil, *Momordica* (B. Uchchhe), Railway creeper. The leaf is simple so long as the blade is in one piece, even though deeply lobed. When the blade is completely dissected into distinct divisions or parts, each being separately inserted on the petiole, the leaf is said to be **compound.**

Fig. 85. Lobed leaves. I, Radish leaf—pinnately lobed; II, Leaf of *Momordica* (B. Uchchhe)—palmately lobed.

Simple and compound leaves

A leaf is said to be simple when it has got a single blade, as in Mango, Jack, China Rose, Cotton, Castor, etc. A *compound* leaf is one whose lamina is made up of two or more distinct segments called *leaflets.*

Compound leaves may be of two types: (i) *palmately compound*—when the leaflets are distinctly articulated at a common point at the top of the petiole, as in Silk cotton; and (ii) *pinnately*

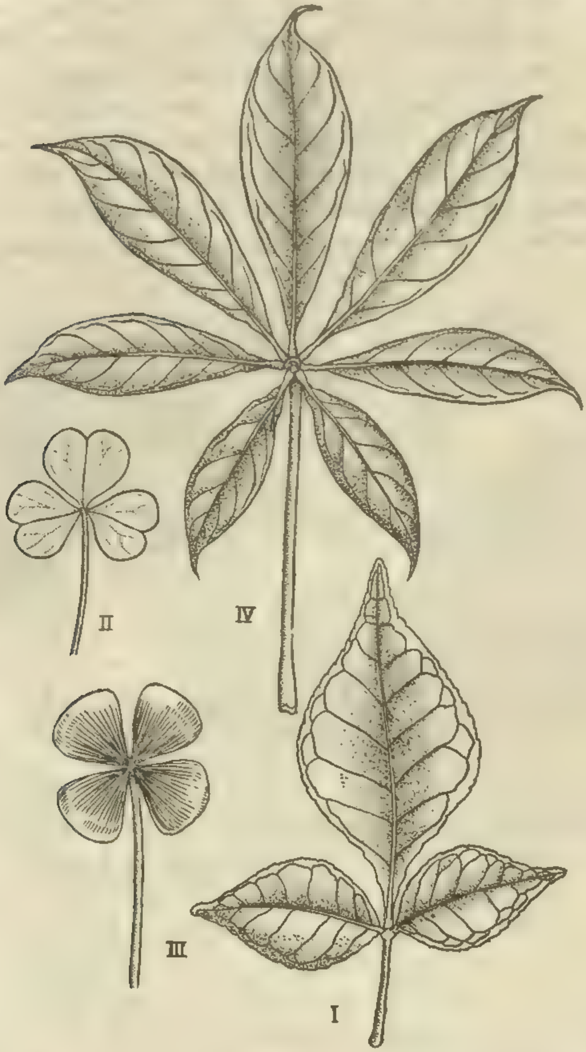


Fig. 86. Palmately compound leaves. I, II, trifoliate; I, leaf of Wood apple; II, leaf of *Oxalis* (B. Amrul); III, *Marsilia* (B. Shushni) leaf—quadrifoliate; IV, Leaf of Silk cotton—multifoliate.

compound—when the leaflets are attached on the two sides of an elongated axis called *rachis*, as in Tamarind, *Melia* (B. Nim), Rose, etc.

Palmately compound leaves [Fig. 86]—According to the number of leaflets arising from the tip of the petiole, the leaves may be: (i) *unifoliate*—when a single leaflet is articulated to the tip of the petiole, as in Lemon [Fig. 93]; (ii) *bifoliate*—with two leaflets, as in *Balanites* (B. Hingan); (iii) *trifoliate*—when there are three leaflets, e.g., Wood apple (B. Bel), *Oxalis* (B. Amrul), Bean; (iv) *quadrifoliate*—with four leaflets, as in *Marsilia* (B. Sushni-sak); (v) *multifoliate* or *digitate*—when five or more leaflets are joined to the petiole, as in Silk cotton (B. Shimul).

Pinnately compound leaves [Fig. 87]—Pinnately compound leaves may be *paripinnate*, when the leaflets are arranged in pairs

Fig. 87. Pinnately compound leaves. I, II, simple pinnate; I, Leaf of Tamarind—paripinnate; II, leaf of *Clitoria* (B. Aparajita)—imparipinnate; III, leaf of Gold-Mohur tree (B. Radhachura)—Bipinnate.

and are always even in number, as in Tamarind, *Cassia* (B. Kalkasunde), and *imparipinnate*, when besides the paired leaflets there

is a terminal leaflet, so that the leaflets are odd in number, as in Rose, *Melia* (B. Nim), *Clitoria* (B. Aparajita).

According to the order of division of the rachis a pinnately compound leaf may be :—(i) *unipinnate* or *simple pinnate*—when the petiole or rachis bears the leaflets directly, as in Tamarind, Rose, *Melia*, etc. (ii) *bipinnate*—when the primary rachis bears secondary branches on which leaflets are produced, as in *Acacia* (B. Babla), *Caesalpinia* (B. Krishna-chura), Gold-Mohur tree (B. Radhachura), etc. ; (iii) *tripinnate*—when the primary axis bears secondary branches which are further branched into tertiary axes on which leaflets are produced, as in *Moringa* (B. Sajina) ; (iv) *decompound*—when the pinnately compound leaf is more than thrice pinnate, as in Coriander (B. Dhania), Fennel (B. Mouri).

Differences between a pinnately compound leaf and a small branch—A pinnately compound leaf is often mistaken for a short branch bearing simple leaves. But they can be distinguished from each other by the following features :—

(i) A short branch always terminates in an apical bud ; a compound leaf can never have an apical bud.

(ii) A short branch arises in the axil of a leaf, the compound leaf develops at a node of the stem, and bears a bud in its axil, from which a branch may arise.

(iii) In the axils of the leaves of a short branch buds are present ; such buds are never present in the axils of the leaflets of a compound leaf.

(iv) When stipules are present they are found at the base of the entire compound leaf, but not at the base of the leaflets.

Phyllotaxy [Fig. 88]

The mode of arrangement of the leaves on the stems and branches is known as *phyllotaxy*. It varies in different kinds of plants.

Importance of phyllotaxy—The object of phyllotaxy is to arrange the leaves on the stem and branches in such a way that they are least interfered with by their neighbours and that all of them can get the maximum amount of sunlight. If the leaves are irregularly arranged on one side of the stem and thus shade one another, then they will not get the proper amount of sunlight which is absolutely necessary for the manufacture of food.

There are three principal types of arrangement of leaves :

(i) *Alternate* or *Spiral phyllotaxy*—When a single leaf

arises at a node alternately on the different sides of the stem, as in Banyan, Custard apple [Fig. 88, I], China Rose, Grasses, etc.

(ii) *Opposite phyllotaxy*—when two leaves arise at a node standing opposite to each other. Opposite phyllotaxy may be (a) *superposed*—when the pairs of opposite leaves stand one upon the other, as in Guava, Rangoon creeper [Fig. 88, II]; and (b) *decussate*—when a pair of opposite leaves stand at right angles

Fig. 88. Types of phyllotaxy. I, leaf of Custard apple—alternate; II, leaf of Rangoon creeper—opposite superposed; III, leaf of *Vinca* (B. Nayantara) —opposite decussate; IV, leaf of *Nerium* (B. Karavi)—whorled.

to the next upper or lower pair, as in *Calotropis* (B. Akanda), *Ocimum* (B. Tulsi), Four-o-clock plant (B. Krishnakali or Sandhyamalati), *Vinca* (B. Nayantara) [Fig. 88, III].

(iii) *Whorled phyllotaxy*—when more than two leaves arise

at a node, e.g., *Nerium* (B. Karavi) [Fig. 88, IV]. *Alstonia* (B. Chhatim).

Leaf mosaic—Leaves of plants growing in the shade or in places where sunlight falls for a short duration only, fit their blades between the neighbouring leaves in such a way that each one gets the maximum amount of sunlight that is possible under the circumstances. In such a case too much overlapping of the leaves is prevented. In certain cases where the leaves are clustered together (rosette plants) the lower leaves usually have longer petioles so that their blades are not shaded by those of the upper leaves ; thus none of the leaves are deprived of the necessary amount of sunlight. This method of leaf distribution is knows as *leaf mosaic* and is found in *Oxalis* (B. Amrul), Garden Nasturtium, Four-o-clock plant, *Acalypha* (B. Muktojhuri), etc.

Kinds of Leaves

1. *Foliage leaves*—The ordinary green leaves of plants are known as foliage leaves.

2. *Cotyledons* or *seed-leaves*—They are the first leaves of the plant and are found in the embryo contained in the seeds. They are always different in shape from the foliage leaves which follow them. The cotyledons are specially modified to perform special functions during the germination of the seed. That they are really leaves can be proved by the fact that in many cases the cotyledons develop leaf-like colour, shape, veins, etc.; like ordinary green leaves they develop buds in their axils even when they are not leaf-like in general appearance.

3. *Scale leaves*—They are relatively small, brownish or yellowish, stalkless leaves which are attached to the stem by a broad base. Being devoid of cholorophyll they cannot manufacture food and are chiefly protective in function. In some cases they may be fleshy and store food products, as in Onion. Scale leaves develop on underground stems, as in the rhizome, the bulb, etc. as well as in aerial shoots, as in young Bamboos. In temperate countries the winter buds of trees are always protected by a number of scale leaves.

4. *Bract leaves*—These are specially modified leaves found associated with a single flower or a cluster of flowers.

5. *Floral leaves*—They occur only in the flowers and are usually found in four whorls. The members of the two inner whorls, called stamens and carpels, are directly responsible for reproduction ; and those of the two outer whorls, called sepals and petals, are only indirectly associated in this matter.

6. *Sporophylls*—The spore-bearing leaves of the Pteridophyta are called sporophylls. The spore-bearing leaves (stamens and carpels) of the flowering plants are also known as sporophylls.

Cauline and Radical leaves—Usually leaves develop on the stems and branches with more or less elongated internodes between them ; such leaves are known as *cauline* (*caulis*—stem). Sometimes leaves may be crowded together near about the top of the root ; these leaves do not develop from the root, but arise from a suppressed or an under-ground stem ; such leaves are said to be *radical* (*radix*—root), as in Radish, *Aloe* (B. Ghritakumari), *SansevIera* (B. Murga), etc.

Dorsiventral, Isobilateral and Centric leaves—Normally the leaves are flattened organs showing two more or less well-defined

surfaces. It is customary to describe the two surfaces of the leaf with reference to their relation to the axis which bears it. The surface of the leaf which is directed towards the axis, is called the *adaxial* or *ventral* (*venter*—the belly) surface and the other surface away from the axis, the *abaxial* or *dorsal* (*dorsum*—back) surface. Such leaves are called *dorsiventral* and are found in most dicotyledons and also in some monocotyledons, as in Banana, Arum, etc. The adaxial surface of a dorsiventral leaf is often called the upper surface, as it is usually directed upwards and the abaxial surface facing downwards is also called the lower surface. In a dorsiventral leaf the adaxial (ventral or upper) surface facing upwards is more strongly illuminated and is deeper green in colour than the abaxial (dorsal or lower) surface. In internal structure also there is much difference between the two surfaces.

In many plants, especially among the monocotyledons, the leaves hang perpendicularly downwards or are held erect and are, therefore, equally illuminated on both surfaces. Such leaves are called *isobilateral* (*isos*—equal, *bi*—two, *lateris*—side). The two surfaces of an isobilateral leaf are uniformly green and show no difference in internal structure.

Leaves like those of Onion which are more or less cylindrical, stand vertically and are equally green all round, are called *centric.*

MODIFICATION OF LEAVES

(1) *Leaf tendrils*—In many plants the leaves are modified into tendrils. They coil round other plants or supports and help the plants which bear them in climbing. In *Lathyrus aphaca* (B. Jangli matar) an entire leaf, in Pea the leaflets of a compound leaf [Fig. 82, IV] and in *Gloriosa* (B. Ulat chandal) the apex of the leaf may be modified into tendrils. The petiole of the leaf may also serve the purpose of the tendril, as in Garden Nasturtium, *Naravelia* (B. Chhagalbati).

(2) *Spine*—Leaves are often modified into short woody pointed structures called *spines.* They usually serve the purpose of defensive weapons, as found in *Opuntia* (B. Phanimanasa) [Fig. 80], Date, etc. In *Opuntia* the stem is modified into phylloclade, in which the leaves fall off very early ; the leaves of the axillary buds of the fallen leaves are all transformed into spines, and so here we find the spines in tufts. Stipules may be modified into spines, e.g., Indian plum [Fig. 82, VI] *Acacia* (B. Babla).

(3) *Leaves modified for the purpose of capturing insects* —There are some plants which capture insects and absorb the food from their bodies after properly digesting them by special means. Such plants are called *carnivorous* or *insectivorous* plants. The leaves of these plants are specially modified for the capture of insects.

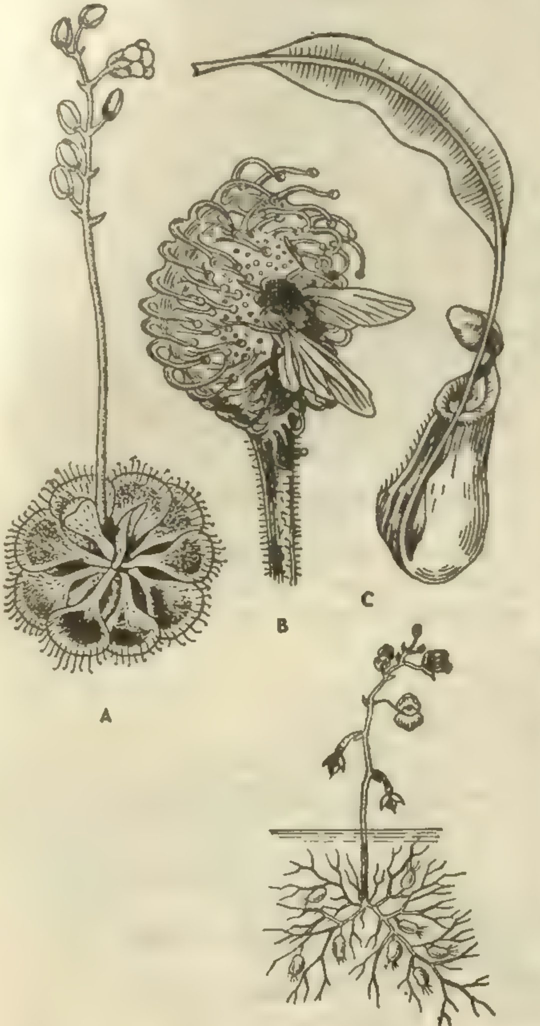


Fig. 89. Insectivorous plants. A, *Drosera ;* B, leaf of *Drosera* enlarged ; an insect has been captured by the tentacles ; C, a leaf of a Pitcher plant with the pitcher ; D, Bladder-wort plant.

(a) *Pitcher* [Fig. 89C] — Leaves of some insectivorous plants are often modified into pitchers. In *Nepenthes* or the Pitcher plant the base of the leaf becomes lamina-like ; the petiole is tendrillar and the lamina is transformed into a pitcher-like structure provided with a lid. With the help of these pitchers the plant captures insects and digests them.

(b) *Bladder* [Fig. 89D]—In Bladder-wort (B. Jhanji), an aquatic plant, the leaves are very much segmented. Some of these segments are modified into small bladder-like bodies ; these act as traps for capturing very small animals. The bladders have

valves which open only inwards ; minute aquatic animals which once get into it, cannot come out. Death eventually occurs and the products of the dead bodies are absorbed by the plant.

(c) *Drosera* [Fig. 89 A, B]—The leaves of this plant are peculiarly modified for the capture of insects. The lamina is more or less circular, and is covered with long radiating hairs or tentacles at the tips of which is secreted a sticky substance. When a small insect alights on the leaf, it is soon caught in the sticky secretion. The tentacles all bend over the insect, which soon dies and its body is decomposed and absorbed by the plant.

Homology and Analogy

Organs are said to be *homologous*, which resemble one another in the origin, however different they may appear externally and whatever their functions may be. Thus the tendril of Passion flower, the thorn of *Duranta* and an ordinary branch are all homologous. Organs which resemble one another in form or in function, but are different in their origin, are described as *analogous*. Thus a phylloclade (modified flat stem) is homologous to a stem, but analogous to a leaf.

THE FLOWER

The *flower* is a modified shoot specially adapted for the purpose of reproduction of the plant. The leaves developed on the floral shoots become highly specialised in order to perform the essential

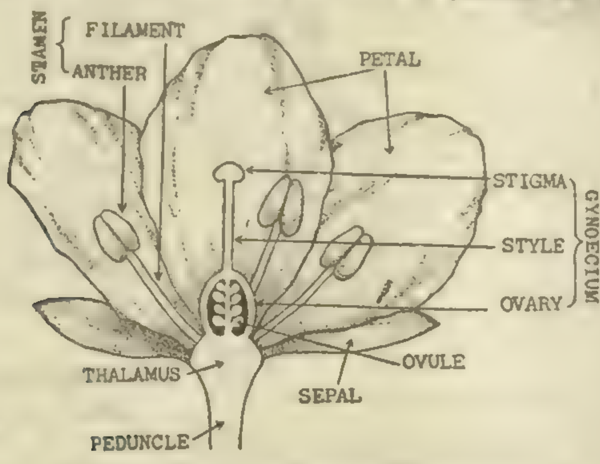


Fig. 90. A typical flower in vertical section.

function of reproduction. The axis of the shoot on which the floral leaves are arranged is called the *thalamus* or *receptacle*. It is the enlarged end of the pedicel or peduncle.

A typical flower [Fig. 99] consists of four whorls of floral leaves arranged on the thalamus. They are the sepals, the petals, the *stamens* and the *carpels*.

(i) The sepals (together called the *calyx*) form the outermost whorl of a flower and develop from the lowermost region of the thalamus. They are usually green in colour and usually enclose the other flower parts in the bud.

(ii) The petals (together known as the *corolla*) form the second whorl of the flower and are usually brightly coloured.

The sepals and petals taken together are known as the *perianth*. But the term perianth is usually used to denote collectively the two outer whorls of floral leaves when there is no distinction in colour between them and so cannot be distinguished as calyx and corolla. When instead of two, only one whorl is present, it is also spoken of as the perianth.

(iii) The stamens (together called the *androecium*) form the third whorl of the flower and constitute its male reproductive whorl. Each stamen consists of a *filament* or stalk on which is developed a special structure called the *anther* containing pollen grains.

(iv) The carpels (together known as the *pistil* or *gynoecium*) constitute the innermost whorl of the flower. The gynoecium consists of : (a) the *ovary*—an enlarged basal part which later on develops into the fruit ; (b) the *style*—a slender tube at the top of the ovary ; (c) the *stigma*—the expanded tip of the style. The gynoecium is the female reproductive whorl of the flower.

In the plant body the flower is the organ of reproduction. The stamens and the pistil are directly concerned with the reproduction of plants and are called the *essential* or *reproductive whorls*. The sepals and petals are not directly responsible but indirectly help in the reproduction and also protect the essential whorls. They are called the *non-essential* or *accessory whorls* of the flower.

Absence of certain parts in flowers. A flower is said to be *complete* when it consists of all the four sets of whorls. When any one of the floral whorls is absent, the flower is said to be *incomplete*. A flower is said to be *bisexual* or *hermaphrodite* when it has both the androecium and the gynoecium, as in Mustard, China Rose, *Datura, etc.* A flower is said to be *unisexual* when it has either androecium or gynoecium, as in Gourd [Fig. 101]. A unisexual fllower is called *staminate* or male when only the stamens are present, and *pistillate* or female when only the pistil

is present. When both stamens and carpels are absent in a flower, it is said to be *neuter*. When staminate and pistillate flowers are present in the same plant, the plant is called *monoecious*, e.g., Gourd; when the staminate flowers are borne in one plant and the pistillate in another, the plants are said to be *dioecious*; example, Palmyra palm, Date palm, Screwpine, etc.

Symmetry of flowers - A flower is said to be *regular* when the members of the different whorls are similar in size and shape. Such a flower can be cut longitudinally into two equal halves along any plane passing through the centre, as in China Rose [Fig. 118], Mustard (Fig. 117), Poppy etc. A flower is said to be *irregular* when the members of any of the whorls are not similar in size and shape, as in [Fig. 119], Bean, *Sesbania* (B. Bak) (Fig. 120), *Ocimum* (B. Tulsi), etc.

The **thalamus** occupies a position at the end of the peduncle or pedicel. It is a very short axis consisting of four nodes, the internodes between them being very much compressed. It is on these four nodes the four sets of floral whorls are arranged. In a few cases the internodes of the thalamus may be elongated and according to their position are named differently. The internode between the calyx and the corolla is called the *anthophore*. The internode between the corolla and the androecium is said to be *androphore*, as found in Passion flower, *Gynandropsis* (B. Swet hurhure) [Fig. 91]. The internode between the androecium and the gynoecium is called *gynophore*, as in *Gynandropsis* (B. Swet hurhure), *Pterospermum* (B. Kanakchampa).

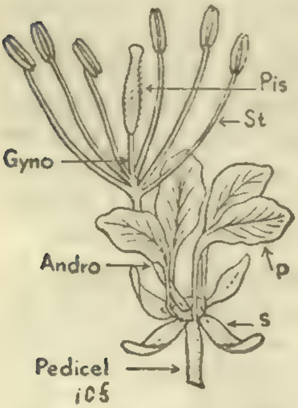


Fig. 91. Flower of *Gynandropsis*. (B. Swet-hurhure) showing the androphore (Andro) and the gynophore (Gyno) s, sepal; p, petal; st, stamen; pis, pistil.

Hypogyny, Perigyny and Epigyny—The construction of the flower varies considerably in accordance with the various developments of the thalamus or receptacle. On account of such developments there exists a great variation in the relation of the different whorls of flowers to one another. According to the mode of insertion of the sepals, petals and stamens below, around and above the

gynoecium, flowers are said to be *hypogynous*, *perigynous* and *epigynous* respectively [Fig. 92]

A flower is said to be *hypogynous* in which the thalamus is more or less convex or conical in form, on the top of which the gynoecium is situated; the androecium, the corolla and the calyx

Fig. 92 Diagrams of (1) hypogynous (2 & 3) perigynous and (4) epigynous flowers.

are inserted below the gynoecium in succession. In such a flower the ovary is said to be superior and the other whorls inferior, e.g., China Rose, Mustard, Brinjal, *Datura*, Custard Apple, etc.

A flower is said to be *perigynous* when the thalamus spreads out into a concave or cup-shaped structure at the centre of which the gynoecium is seated; at the rim of the cup-shaped thalamus develop the sepals, petals and stamens, which seem to be arranged around, instead of below, the gynoecium. In this case also, the ovary is said to be superior. Examples, Pea, *Sesbania* (B. Bak), Rose, etc.

When the thalamus not only becomes cup-shaped but is completely fused with the lower part of the gynoecium, so that the calyx, corolla and androecium are inserted above the ovary, the flower is said to be *epigynous*. In an epigynous flower the ovary is said to be inferior and the other floral members superior. Examples, Gourd, Cucumber, Sunflower, etc.

The **Calyx** is the outermost set of floral leaves and composed of a number of sepals which are usually green, but sometimes they may be coloured. When the sepals are free, the calyx is said to be *polysepalous*; when they are united, the calyx is *gamosepalous*.

If the sepals fall off at the time of the opening of the flowers, they are said to be *caducous*, as in Poppy, Mexican Poppy (B. Shealkanta). They are *deciduous* when they fall off along with the petals after the fertilization of the flower has taken place, as in Mustard, China Rose. Sepals are said to be *persistent* when they persist up to the fruiting stage and remain attached to the

fruit, as in *Datura*, Brinjal. In some cases the sepals not only persist, but grow in size and form a part of the fruit. Such sepals are called *accrescent* and are found in *Dillenia* (B. Chalta). *Physalis* (B. Tepari), *Shorea* (B. Sal), etc.

In plants of the Sunflower family the calyx is modified into two or more scaly or hairy structures known as *pappus*. Sometimes the calyx instead of being green in colour becomes enlarged and brightly coloured and performs the function of petals; such a calyx is said to be *petaloid*. In *Mussaenda*, a common shrubby plant grown in gardens, only one of the sepals becomes petaloid.

The **corolla** is the inner set of accessory whorls and is composed of a number of petals. The petals are usually delicate in texture and in tint. Normally they are brightly coloured and are often scented, and serve to attract insects to visit flowers. Occasionally the petals are green like sepals and are then called *sepaloid*, as in *Polyalthia* (B. Debdaru), Custard apple.

The *corolla* is *polypetalous* when the petals are all free; it is *gamopetalous* when the petals are more or less united together. In a polypetalous corolla the individual petals often have short or elongated stalks called *claws*. A petal having a claw is said to be *clawed*, as in Mustard [Fig. 97, 3].

The corolla is *regular* when the petals are all similar in size and form; it is *irregular* when the petals are not similar in shape and size and are not arranged symmetrically.

Androecium—A stamen usually has two parts: (i) *filament*, a slender stalk of the stamen and (ii) the *anther*, a swollen structure at the top of the filament. The anther usually consists of two lobes separated by a projection of the filament called the *connective*. Each lobe of the anther contains two chambers called *pollen sacs*; so, there are altogether four pollen sacs in an anther. The pollen sacs are filled up with minute dust-like structures called *pollen grains* [Fig. 93A].

In certain flowers some stamens do not develop fertile anthers and thus become abortive or sterile. Such sterile stamens are known as *staminodes*, as in *Cassia* (B. Kalkasunde). Sometimes the staminodes become petaloid, as found in *Canna*. The pollen grains usually remain free in the pollen sacs; but in some cases the pollen grains in the anthers cohere into masses called *pollinia*, as in *Calotropis* (B. Akanda), Orchid. In *Calotropis* the pollinia are found in pairs.

Fixation of anthers on the filament—The mode of attachment

of the anther to the filament varies in different plants. It may be of the following types: (i) *Innate* or *basifixed*—when the fila-

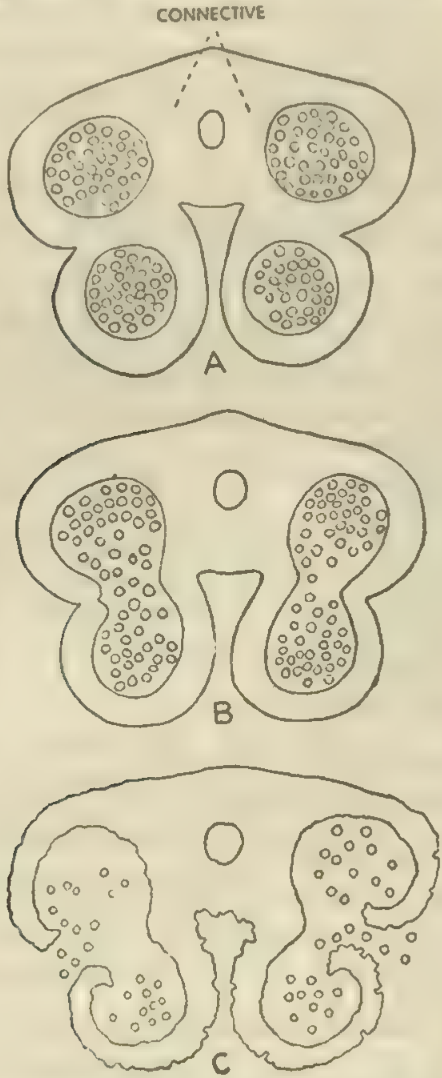


Fig. 93. A, transverse section of anther with four pollen sacs containing pollen grains. B, the same before dehiscence; the two pollen sacs of each anther lobe have coalesced and formed one cavity; C, the same at the time of dehiscence.

ment is attached to the base of the anther, as in Mustard [Fig. 97, 4]. (ii) *Adnate*—when the filament is attached to the back of

the anther throughout its whole length ; as in *Michelia* (B. Champa), Water Lily. (iii) *Dorsifixed*—when the filament appears to be inserted at the back of the anther, as in Passion flower (B. Jhumka-lata), *Polyanthes* (B. Rajanigandha), *Sesbania* (B. Bak) [Fig. 100, 5]. (iv) *Versatile*—when the filament is attached to the back of the anther by a fine point so that the anther swings freely, as in Paddy, Grasses.

Dehiscence of anthers—It has been mentioned above that the pollen grains are formed in the four pollen sacs of the anther. When the anther matures the two pollen sacs of each anther lobe usually coalesce and form one cavity, within which the pollen grains remain free [Fig. 93B]. The pollen grains are important male reproductive structures which must be brought into contact with the famale reproductive structures for the production of seeds, without which there can be no reproduction. The first step towards this end is the shedding of the pollen grains. This takes place by the bursting or dehiscence of the anthers. Dehiscence may take place in several ways.

Relative length of stamens—The filaments of the stamens of a particular flower are usually all of the same length ; but sometimes a flower has stamens of unequal length. Thus in *Ipomea* (B. Kalmi) there are five stamens of which some are longer and others shorter without having definite relation to each other. But in Mustard and Radish there are six free stamens of which two are short and four long [Fig. 97] ; besides, the stamens are arranged in two whorls ; the two shorter stamens are in the outer whorl and the four longer ones in the inner. Thus there is a definite relation between the short and long stamens so far as their arrangement and position are concerned. Such stamens are called *tetradynamous*. Stamens are said to be *didynamous* when there are four free stamens of which two are short and two long, as in *Ocimum* (B. Tulsi) [Fig. 103], *Leucas* (B. Swet drona), *Leonurus* (B. Rakta drona).

Union of stamens—The stamens may remain free or may be united together. Union may take place in the region of the filaments only or in the region of the anthers only, the filaments remaining free. Stamens are said to be (i) *monadelphous* [Fig. 98] when they are united into one bundle by their filaments, the anthers remaining free, as in China Rose, Cotton ; (ii) *diadelphous* [Figs. 99, 100]—when they are united by their filaments into two bundles, as in Pea, Bean, *Sesbania* (B. Bak) ; (iii) *polyadel-*

phous—when they are united by their filaments into more than two bundles, as in Orange, Silk Cotton; (iv) *syngenesious*—when the anthers are united into a ring, but the filaments remain free, as in Sunflower, Marigold, Gourd [Fig. 101, 2].

Union of stamens with other whorls—Stamens are said to be *epipetalous* when they are attached to the petals, as in *Datura* [Fig. 102], Brinjal, etc. Nearly all flowers with gamopetalous corolla have epipetalous stamens. When the stamens are attached to the gynoecium, they are said to be *gynandrous,* as in *Calotropis* (B. Akanda).

The **gynoecium** or **pistil** may be composed of a single carpel, as in Pea, Bean, etc. and in such case it is said to be *monocarpellary.* It may consist of two or more carpels and then it is called *polycarpellary.* In a polycarpellary gynoecium the carpels may remain free, as in *Michelia* (B. Champa) Custard Apple, *Artabotrys* (B. Kantali champs), Lotus, Rose [Fig. 94], etc., or may be more or less united, as in China Rose, Mustard, Gourd. *Polyanthes* (B. Rajanigandha); in the first case the gynoecium is called *apocarpous* and in the second case it is *syncarpous.*

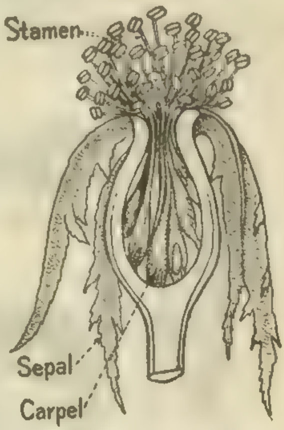


Fig. 94. A flower of wild Rose (from which the petals have been removed) cut longitudinally to show the apocarpous pistil.

The ovary contains within it a number of small rounded bodies called *ovules.* From the ovary the fruit is developed and the ovules are destined to become the seeds.

Normally the *style* develops from the top of ovary, but in the gynoecium of flowers of *Ocimum* (B. Tulsi) *Leonurus* (B. Rakta drona), etc. the style appears to develop from the base of the depression of the four-lobed ovary; such a style is called *gynobasic* [Fig. 103].

The *stigma* is the receptive surface of the pollen grain and is found at the apex of the style. It may be swollen and knob-like, or flattened, or elongated. When the carpels are separate, each carpel has its own stigma. When the carpels are united below, each carpel may have a separate stigma, as in China Rose [Fig. 98], Cotton; the union of the carpels may extend upwards and consequently a single stigma may be formed, as in *Datura*

[Fig. 102]. The single stigma may be lobed, the lobes corresponding to the number of carpels.

Placentation—The surface on the inner walls of the ovary on which the ovules are borne and which is often more or less swollen, is called the *placenta.* The placentas develop by the union of the margins of the carpels. They may also develop from the base of the ovary. The way in which the placentas are arranged is called *placentation.* In most flowers the number of placentas is the same as the number of carpels in the gynoecium.

Types of Placentation [Fig. 95] 1. *Marginal*—In this case the ovary is monocarpellary and unilocular, and there is only one placenta developed by the united margins of the single carpel, as in Pea, Bean, etc.

2. *Parietal*—When the placentas are formed on the inner wall of the ovary. This type of placentation is found in unilocular

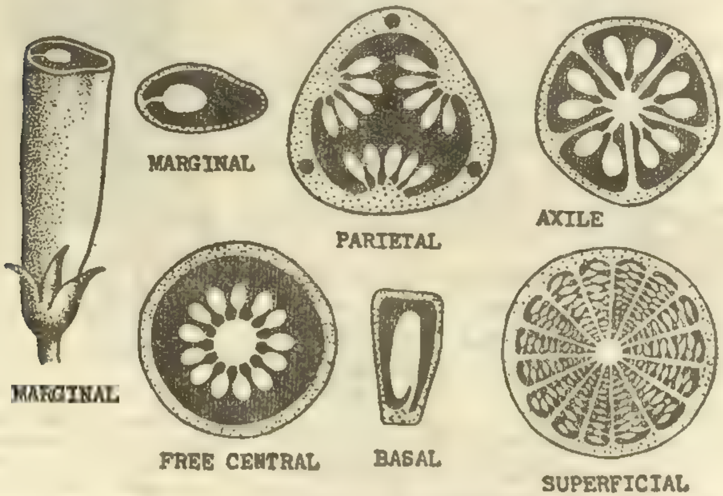


Fig. 95. Types of Placentation.

ovaries composed of two or more carpels, as in Mustard, Papaw, Poppy, Mexican Poppy (B. Shealkanta), Passion flower.

3 *Axile*—This is found in multilocular ovaries in which the placentas are borne on the axis of the ovary, as in China Rose, Cotton.

4. *Free-central*—In this case the ovules develop on the central axis of a unilocular ovary, the axis not being connected by partitions with the walls of the ovary. This type of placentation is found in Pink, *Portulaca* (B. Gima-sak).

5. *Basal*—When the placenta is situated at the base of a unilocular ovary from which a single ovule is developed, as in Shnflower.

6. *Superficial*—When the ovary is multilocular and the ovules arise only from the partition walls of the chambers, the placentation is known as superficial, as in Water lily.

The Ovule [Fig. 96A & 96B]—Ovules are small oval bodies developing from the placentas within the ovary. The number of

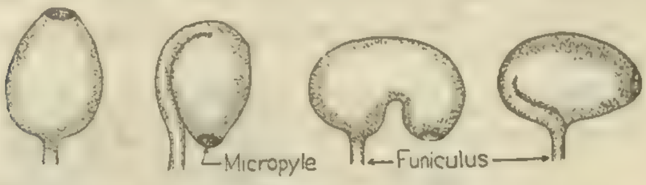


Fig. 96A. Forms of ovules—From left to right : orthotropous, anatropous, campylotropous and amphitropous.

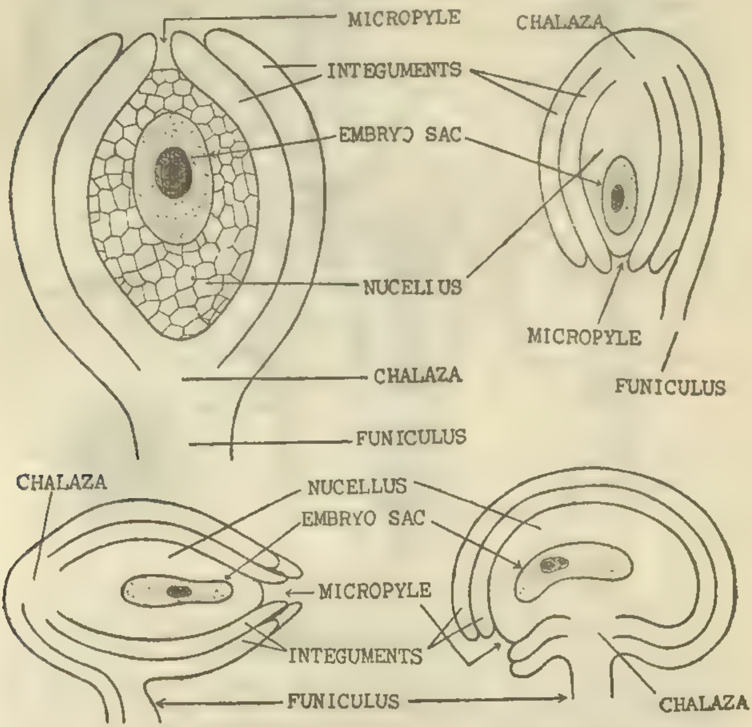


Fig. 96B. Vertical section of ovules—Top : left, Orthotropous, right, Anatropous, Bottom : left, Amphitropous, right, Campylotropous ovules.

ovules in an ovary may range from only one, as in Sunflower, Paddy, Wheat, etc. to hundreds, as in Gourd, Poppy, Tobacco, etc. Each ovule is attached to the placenta by a short stalk called the *funiculus.* The main body of the ovule consists of a soft tissue called the *nucellus*, which is invested usually by two coats called the *integuments.* The integuments do not completely cover the nucellus, a small opening being left at the apex; this is called the *micropyle.* The point at the base of the nucellus from which the integuments develop is called the *chalaza.* Within the nucellus close to the micropyle there is a very big cell called the *embryo-sac.*

Forms of Ovules Fig. 96

1. *Orthotropous or straight*—when the ovule is an erect body with the chalaza and the micropyle in one straight line. In such an ovule the chalaza is situated at the base and the micropyle at the apex of the

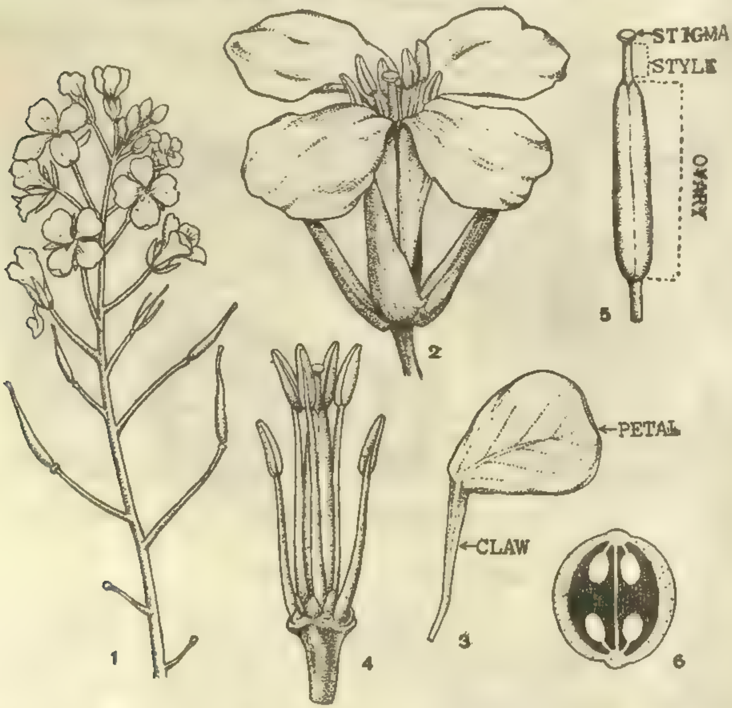


Fig. 97. Mustard. 1, inflorescence; 2, a flower; 3, a single petal; 4, tetradynamous stamens; 5, pistil or gynoecium; 6, transverse section of ovary showing placentation.

ovule far removed from the chalaza, as in *Betel, Polygonum* (B. Panmarich). 2. *Anatropous or inverted*—when the ovule bends in such a way on account of the greater growth of the funiculus so that the micropyle lies close to the placenta. Here also the chalaza and the micropyle are in the same straight line. The upper part of the funiculus is adherent to

the side of the ovule, as in Bean, Castor. 3. *Campylotropous*—when the ovule is bent upon itself in such a way that the micropyle is brought down close to the chalaza, as in Mustard, Krishnakali. 4. *Amphitropous* or *transverse*—when the ovule is placed transversely, that is, placed at right angles to the funiculus, as in Poppy. This kind of ovule is rather rare.

DESCRIPTIONS OF A NEW COMMON FLOWERS

I. Mustard [Fig. 97]

Inflorescence—raceme.

Flower—pedicellate, ebracteate, bisexual, complete, regular, hypogynous.

Calyx—sepals 4, polysepalous.

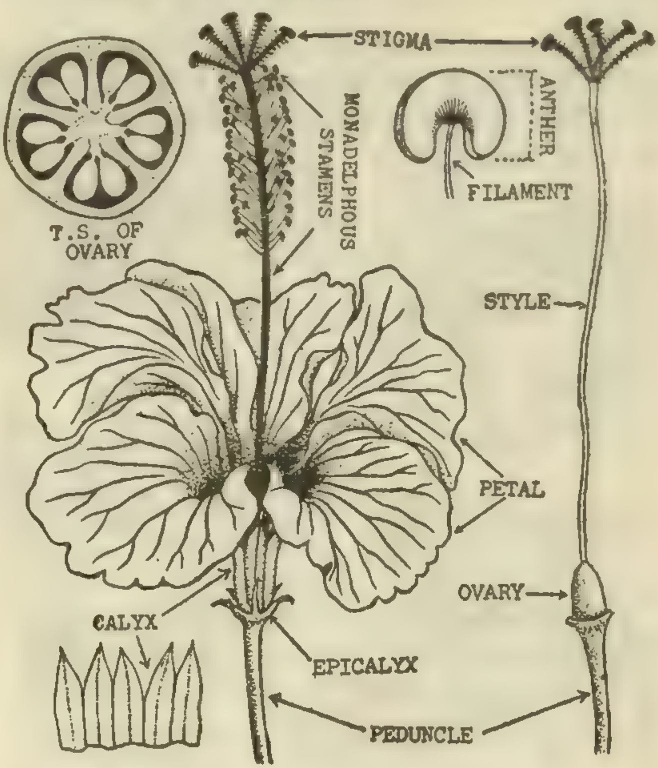


Fig. 98. Flower of China Rose and its different parts.

Corolla—petals 4, polypetalous, clawed, cruciform, colour yellow.

Androecium—stamens 6, in two whorls, 2 short in the outer whorl, 4 long in the inner whorl (tetradynamous); anthers basifixed.

Gynoecium—carpels 2, syncarpous; ovary superior, 2-celled, ovules many in each chamber; placentation parietal.

II. China Rose (B. Java) [Fig. 98]

Flower—pedunculate, bisexual, complete, regular, hypogynous. A whorl of bracteoles is found below the calyx forming what is known as the epicalyx.

Calyx—sepals 5, gamosepalous, tubular.

Corolla—petals 5, slightly united at the base, aestivation twisted, colour red.

Androecium—stamens many, monadelphous, epipetalous, the staminal column encloses the ovary and the style; anthers reniform, unilocular.

Gynoecium—carpels 5, syncarpous, ovary superior, 5-chambered with many ovules in each chamber; placentation axile; style slender, passing through the staminal column; stigmas 5, free.

III. Pea [Fig. 99]

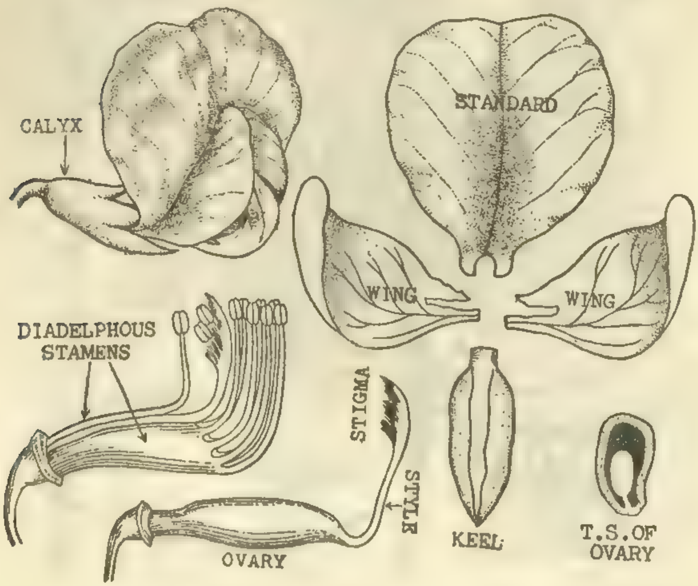


Fig. 99. Pea flower and its different parts.

Flower—pedicellate, ebracteate, bisexual, complete, irregular, perigynous.

Calyx—sepals 5, gamosepalous.

Corolla—petals 5, of the petals the outermost is the largest and

is called the *standard* or *vexillum* ; the two lateral ones are known as the *wings* or *alae*, and the two innermost ones are the smallest and are united to form a boat-shaped structure called the *keel* or *carina* (papilionaceous); aestivation vexillary.

Androecium—stamens 10, in two bundles; the filaments of 9 stamens are united into one bundle and the other one remains free (diadelphous); anthers dorsifixed; perigynous.

Gynoecium—monocarpellary, ovary superior, one-celled with 5-10 ovules, placentation marginal.

IV. Sesbania (B. Bak-ful) [Fig. 100]

Description of parts as in Pea.

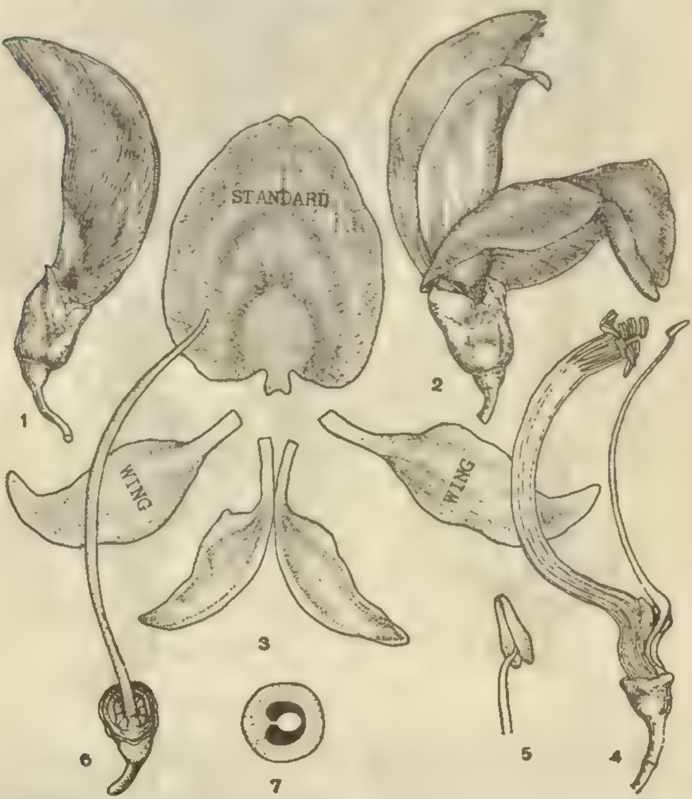


Fig. 100. *Sesbania* (B. Bak-ful). 1, a flower bud ; 2, an open flower ; 3, petals dissected open ; 4, diadelphous stamens ; 5, dorsifixed anther ; 6, gynoecium showing the elongated ovary and the short style ; note the position of the gynoecium in the concave thalamus ; 7, transverse section of ovary showing marginal placentation.

V. Gourd [Fig. 101]

Flowers [illegible]

Staminate (Male) flower

Calyx—sepals 5, united at the base, free above; lobes of calyx linear.

Corolla—petals 5, gamopetalous, campanulate, usually yellow.

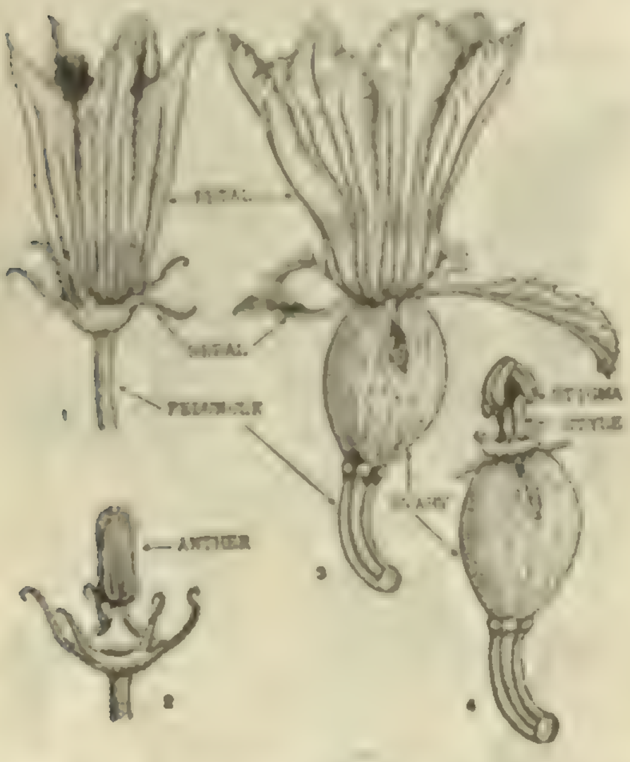
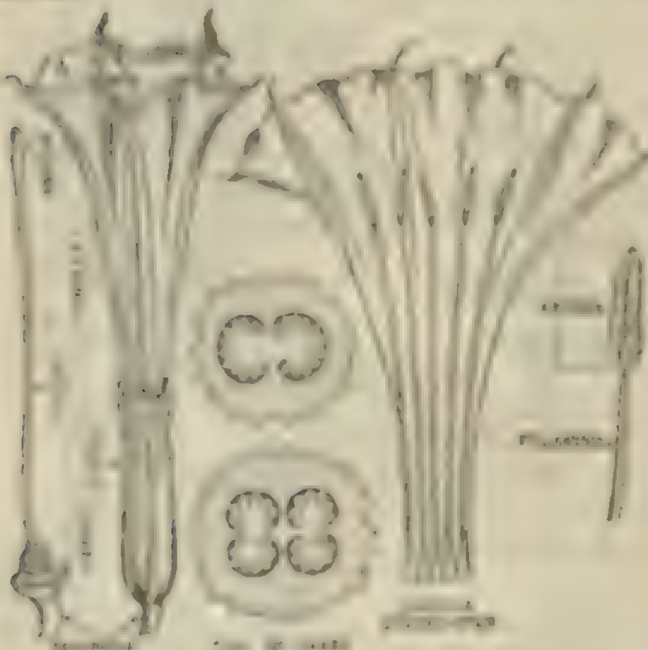


Fig. 101. Gourd. 1, a staminate flower; 2, the same after removing the petals showing the syngenesious stamens; 3, a pistillate flower; 4, the same after removing the sepals (partly) and the petals.

Androecium—stamens 3, united by their anthers, filaments remaining free (syngenesious); anther lobes sinuous, that is twisted up and down in the form of transverse "S".



bifid

VII. Ocimum (B. Tulsi) [Fig. 103]

Inflorescence—terminal cymes.

Flower—sessile, bracteate, bisexual, complete, irregular, hypogynous.

Calyx—sepals 5, gamosepalous, bilabiate.

Corolla—petals 5, gamopetalous, bilabiate.

Androecium—stamens 4, epipetalous, two short and two long (didynamous).

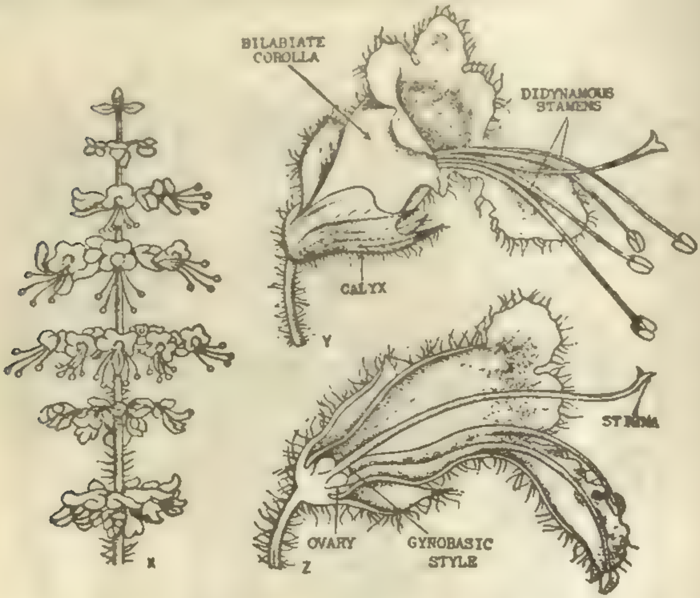


Fig. 103. Flower of *Ocimum* (B. Tulsi). X, Inflorescence ; Y, one flower, Z, flower cut vertically.

Gynoecium—carpels 2, syncarpous, ovary superior, 4-lobed and 4-chambered with only one ovule in each chamber ; placentation axile ; style gynobasic, stigma bifid.

VIII. Polyanthes (B. Rajanigandha) [Fig. 104]

Inflorescence—spike.

Flower—sessile, bracteate, bisexual, regular, epigynous.

Perianth—6, in two whorls, united, colour white.

Androecium—stamens 6, free, attached to the perianth lobes, anthers dorsifixed.

Gynoecium—carpels 3, syncarpous ; ovary inferior, 3-locular, with many ovules in each chamber, placentation axile ; style

elongated; stigma shortly 3 lobed.

THE SEED

As the result of fertilization the ovule increases greatly in size and is transformed into the seed. A series of changes takes place in the ovule when it is converted into the seed. The two integuments become thick and form the two seed coats (*testa* and *tegmen*) of the seed. The nucellus of the ovule usually disappears in the seed condition, but in some seeds, as in Water lily, Cardamom, etc. it becomes a food-storing region of the seed called the *perisperm*.

In some cases the endosperm is used up by the embryo during its development. In such a case the ripe seed contains no endosperm; such a seed is said to be *exalbuminous* or *non-endospermic*, e.g., Pea, Bean, Mango, etc. In other cases the embryo

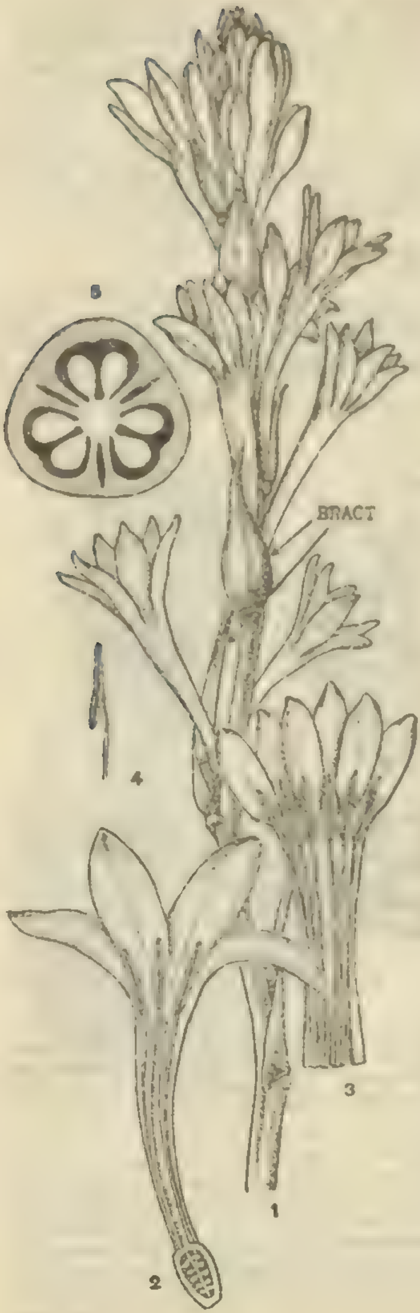


Fig. 104. *Polyanthes.* (B. Rajanigandha). 1, inflorescence; 2, a flower cut vertically; 3, perianth spread open; 4, dorsifixed anther; 5, transverse section of ovary showing axile placentation.

does not use up all the endosperm, so that the mature seed contains not only the embryo, but also some amount of endosperm. Such a seed is called *albuminous* or *endospermic*, e.g., Castor, Paddy, Maize, Wheat, etc.

Occasionally the seed is invested by an extra integument which develops after fertilization. Such an integument is called *aril*. It may be fleshy on some cases, as in Litchi.

THE FRUIT

Normally the fruit is the matured ovary of the flower. Sometimes, other parts of the flower are also associated in the structure of the fruit. The fruit is thus the result of the growth induced in the ovary and occasionally also in some other parts of the flower by the effect of fertilization.

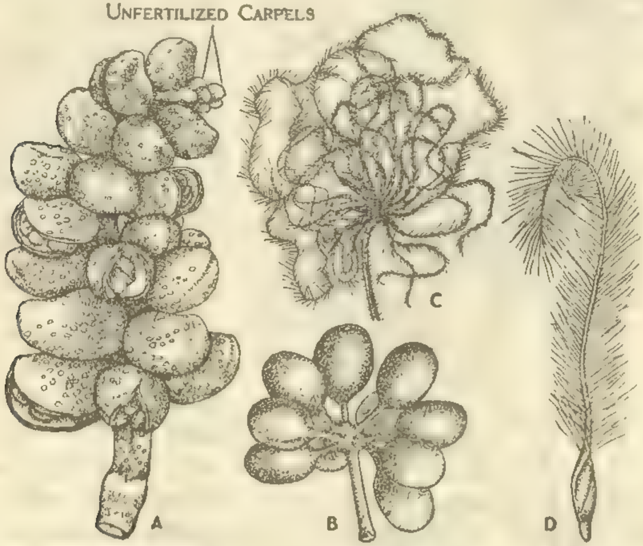


Fig. 105. Some aggregate fruits. A, aggregate of follicles of *Michelia* (B. Champa); B, an aggregate of berries of *Polyalthia* (B. Devdaru); C, an aggregate of achenes of *Naravelia* (B. Chhagalbati); D, a single achene of *Naravelia* with the persistent feathery style (enlarged).

True and false fruits—A *true fruit* is one which develops only from the ovary, e.g., Mango. A *spurious* or *false fruit* is one in which other parts of the flower besides the ovary take part in the formation of the fruit: (i) In *Dillenia* (B. Chalta) and *Physalis* (B. Tepari) the sepals not only become persistent, but grow with the ovary and form a part of the fruit; (ii) In Apple and Pear, the cup-shaped thalamus completely encloses the carpels, becomes fleshy and forms the fruit; the carpels which are five in number remain inside and form the central core (Fig. 130).

Parts of Fruits—The wall of the ovary which ripens into the wall of the fruit enclosing one or more seeds forms the *pericarp*. In dry fruits the pericarp is usually thin, but in fleshy fruits it is usually thick and can be distinguished into three parts: (i) *Exocarp* or *Epicarp* the outermost layer which forms the skin of the fruit. (ii) *Mesocarp*—the middle layer which usually forms the succulent or fibrous portion of the fruit. (iii) *Endocarp*—the innermost layer which may be stony or membranous.

Kinds of Fruits

1. *Simple fruits*—developed from the single ovary of a flower, e.g., Mango, Mustard, Pea, etc. Most of the common fruits are simple fruits.

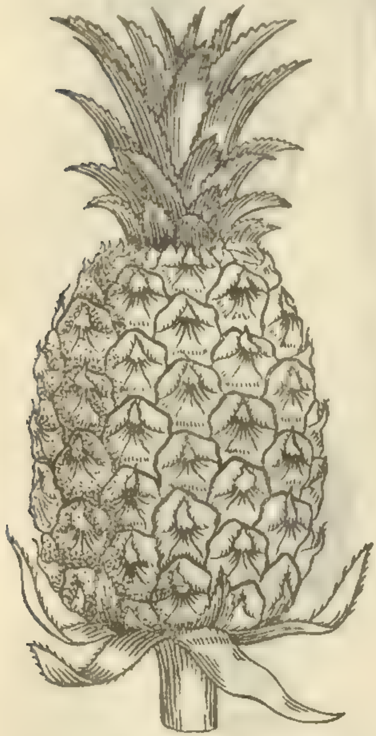


Fig. 106. Fruit of Pineapple.

2. *Aggregate fruits*—developed from a number of ovaries belonging to a single flower (apocarpous pistil), e.g., *Lotus*, *Michelia* (B. Champa), Rose, *Naravelia* (B. Chhagalbati), *Artabotrys* (B. Kantali champa) [Fig. 105]. Each one of the small fruits of an aggregate fruit is called a fruitlet and is developed from a single ovary. An aggregate fruit is, therefore, composed of a number of fruitlets which are the products of a single flower.

3. *Multiple* or *Collective fruits*—developed from the ovaries of a number of flowers belonging to an inflorescence, all of which usually coalesce into a mass. Multiple fruits may be of two kinds: (i) *Syconus*—It is developed from a hypanthodium with a hollow fleshy receptacle. It contains within it many small fruits developed from the pistillate flowers of the inflorescence, e.g., Fig, Banyan, etc. (ii) *Sorosis*—It is a multiple fruit which develops from a spike or spadix. The axis of the inflorescence, and the

ovaries and the perianth leaves of the flowers, all grow simultaneously and are fused together forming a single fleshy mass, e.g., Pineapple [Fig. 106], Jack-fruit, Mulberry (B. Toont).

Simple Fruits

These may be *dry* or *fleshy*. In the dry fruits, the pericarp is dry; they are said to be *dehiscent*, when they dehisce or burst in order to liberate their seeds, and *indehiscent*, when they do

Fig. 107. Some dry dehiscent fruits. 1, Legume of Pea; 2, the same showing dehiscence; 3, Follicle of *Calotropis* (B. Akanda); 4, Siliqua of Mustard; 5, the same showing dehiscence. The seeds are seen to remain attached to the replum. 6, Capsule of *Datura*.

not dehisce or burst. Indehiscent fruits are usually small and one-seeded. In an indehiscent fruit the seed is retained within the fruit until ready for germination.

Dry Dehiscent Fruits [Fig. 107]

1. *Legume or Pod*—It is a superior, monocarpellary, dry fruit which dehisces by cracking open along two lines into two parts called valves, e.g., Pea, Bean, etc.

2. *Follicle*—It is a superior, monocarpellary, dry fruit. A follicle resembles a legume except in one respect; it dehisces only along the side which bears the seeds, e.g., *Calotropis* (B. Akanda).

3. *Siliqua*—It is a superior bicarpellary, many-seeded fruit which dehisces from below upwards into two parts. The seeds in this case remain attached to the false partition wall-the *replum*, e.g., Mustard.

Fig. 108. A, capsule of Lady's finger, B, the same showing loculicidal dehiscence.

4. *Capsule*—It is a superior, bi-or poly-carpellary, many-seeded fruit which may dehisce by various ways.. A capsule is usually composed of many chambers; it may also be one-cham-

bered, e.g., Cotton, *Datura*, Poppy, Lady's finger [Fig. 108], *Gynandropsis* (B. Hurhure), etc.

Dry Indehiscent Fruits [Fig. 109]

1. *Achene*—It is a dry, indehiscent, one-seeded fruit in which the pericarp is not fused with the seed coat and is developed from a superior monocarpellary ovary, e.g., *Naravelia* (B. Chhagalbati).

2. *Caryopsis*—It is a small, dry, indehiscent, one-seeded fruit resembling an achene, in which the pericarp closely adheres to the testa of the seed, e.g., Paddy, Wheat, Maize, etc.

Fig. 109. Some dry indehiscent fruits. A, caryopsis of Wheat ; B. cypsela of Sunflower ; C, samara of *Dioscorea* (B. Kham-alu) ; D, samara of *Shorea* (B. Sal) ; E, nut of Oak ; F & G, schizocarp of Carrot ; H & I, schizocarp of Anise (B. Mouri). In G & I, the schizocarps have broken up in two parts.

3. *Cypsela*—It is a dry indehiscent one-seeded fruit developed from an inferior bicarpellary ovary. It resembles an achene but differs from it in being developed from an inferior bicarpellary ovary. Examples, Sunflower, Marigold, etc.

4. *Nut*—The nut is a dry, indehiscent, one-seeded fruit in which the pericarp becomes hard and woody, e.g. Oak.

5. *Samara*—It is a dry, indehiscent fruit in which the pericarp develops a wing-like outgrowth, e.g., Ash, *Hiptage* (B. Madhabilata), *Dioscorea* (B. Chupri-alu or Kham-alu). The fruit of *Shorea* (B. Sal) is also a samara, but in this the sepals grow and develop into wings.

6. *Schizocarp*—It is a peculiar indehiscent fruit developed from an inferior bicarpellary ovary. When mature, it breaks up

into two one-seeded parts, e.g., Coriander (B. Dhania), Ajowan, Anise (B. Mouri), Carrot, etc.

Fleshy Fruits [Fig. 110]

(i) *Drupe*—It is a fleshy, one-celled and usually one-seeded fruit in which the pericarp can be distinctly separated into three parts : *exocarp* or *epicarp*, the soft outer portion forming the skin ; *mesocarp*, the fleshy middle portion, and *endocarp*, the very hard stony inner layer enclosing the seed, e.g., Mango, Indian plum, Olive, Peach, etc.

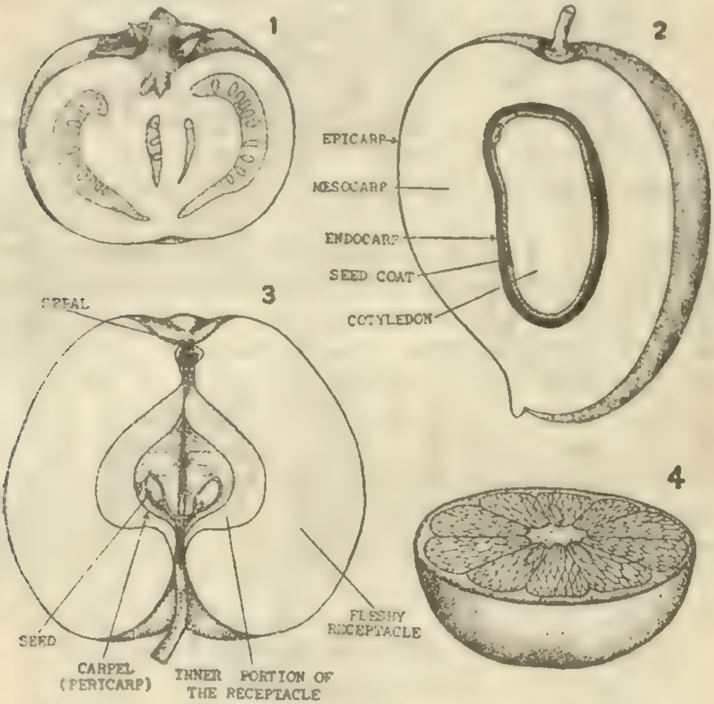


Fig. 110. Some fleshy fruits. 1, Vertical section of a Tomato ; the pericarp is fleshy throughout. 2, Drupe of Mango cut vertically to show the different parts. 3, Fruit of Apple, a pome, cut vertically showing the different parts. 4, Transverse section of an Orange, a hesperidium, showing the different parts.

(ii) *Berry*—The berry is a many-seeded soft fruit in which the whole pericarp becomes thick and fleshy. It may develop from a superior or inferior ovary, e.g., Banana, Brinjal, Tomato, Guava, etc. The Date is a one-seeded berry ; its endocarp is thin and membranous ; the "stone" is actually the seed.

PLANT KINGDOM

- Phanerogams or Spermatophyta (Flowering plants or Seed plants)
  - Angiosperms
    - Dicotyledons
      - Polypetalae (Flowers complete ; corolla polypetalous)
        - Family
          1. Cruciferae
          2. Malvaceae
          3. Leguminosae
          4. Cucurbitaceae
          - Genus
            - Species
      - Gamopetalae (Flowers complete ; corolla gamopetalous)
        - Family
          1. Compositae
          2. Solanaceae
          - Genus
            - Species
      - Incompletae (Flowers incomplete. usually unisexual)
        - Family Euphorbiaceae
          - Genus
            - Species
    - Monocotyledons
      - Petaloidae (Perianth petaloid)
        - Family Liliaceae
          - Genus
            - Species
      - Spadiciflorae (Flowers in spadix, enclosed by a spathe)
        - Family Palmaceae
          - Genus
            - Species
      - Glumiflorae (Flowers enclosed in scaly bracts called glumes)
        - Family Graminaceae
          - Genus
            - Species
  - Gymnosperms e.g., Pine
- Cryptogams (Non-flowering plants or Seedless plants)
  - Pteridophyta e.g., Fern, Selaginella
  - Bryophyta e.g., Riccia, Moss
  - Thallophyta
    - Algae e.g., Spirogyra, Chlamydomonas
    - Fungi e.g., Mucor, Penicillium

N. B.—In this schedule only Families described in this book are given.

(iii) *Pepo*—It is a kind of berry in which the rind is very tough. The fruit is developed from an inferior ovary, e.g., Gourd, Cucumber.

(iv) *Hesperidium* The hesperidium is a kind of berry developed from a superior ovary. In this fruit the epicarp and mesocarp are fused together to form a thick and leathery rind and the endocarp forms the juicy portion. The juice is contained in special glandular hairs developed from the inner walls of the endocarp, e.g., Orange, Lemon. In the common orange there are a few chambers, each representing a carpel.

(v) *Pome*—This is a fleshy, many-seeded fruit developed from the ovary of an epigynous or perigynous flower. The thalamus or receptacle completely encloses the ovary; after fertilization it enlarges considerably and forms the fleshy edible portion of the fruit. The central part containing the seeds is developed from the carpels and is the real pericarp of the fruit. Example: Apple, Pear.

Some peculiar fruits—The coconut is not a nut but is a fibrous drupe, because the mesocarp becomes fibrous. The endocarp is hard and stony and contains only one seed within. The seed is surrounded by a brownish seed coat, and has abundant endosperm and a small undifferentiated embryo. The Black-berry (B. Kalojam) is a drupe. The Litchi is not really a fleshy fruit, that is, the fleshy portion is not developed from the pericarp. It is an outgrowth of the funiculus of the seed and is called the aril. The Custard Apple (B. Ata) is really an aggregate fruit, developed from the free carpels of a single flower. During development, all the carpels coalesce together to form a single fleshy fruit.

FAMILIES OF DICOTYLEDONS

POLYPETALAE

Family 1. Cruciferae

Common plants—Mustard, Radish (Fig. 111), Cabbage, Cauliflower, Kohl-rabi (B. Ol Kapi), Turnip, etc.

Plants—herbs, often with pungent juice.

Leaves—radical or cauline, simple, alternate, exstipulate, pinnately lobed (lyrate).

Flowers—pedicellate, ebracteate, bisexual, complete, regular, hypogynous.

(i) *Calyx*—sepals 4 in two whorls, polysepalous.

(ii) *Corolla*—petals 4, polypetalous, clawed, cruciform.

(iii) *Androecium*—stamens 6 in two whorls, 2 short in the outer whorl, 4 long in the inner whorl (tetra-dynamous); anthers basifixed.

(iv) *Gynoecium*—bicarpellary, syncarpous, ovary superior, becomes 2-chambered by the development of a false partition wall called *replum* ; ovules several in each chamber ; placentation parietal.

Fruit—a siliqua. *Seeds*—exalbuminous ; cotyledons oily.

Fig. 111. A Radish plant with the swollen fusiform root ; B, flowering shoot ; C, a flower ; D, a clawed petal ; E, flower from which sepals and petals have been removed ; F, transverse section of ovary showing placentation ; G, floral diagram.

Family 2. Malvaceae

Common plants—China Rose, Cotton (Fig. 112), Lady's finger, *Hibiscus mutabilis* (B. Sthal-padma), *Abutilon*, Madras Hemp, etc.

Plants—herbs, shrubs or trees, mucilaginous.

Leaves—simple, alternate, stipulate, venation palmately reticulate

Flowers – pedicellate, bisexual, complete, regular, hypogynous. A whorl of bracteoles is present below the calyx forming what is known as the *epicalyx*.

(i) ***Calyx*—sepals 5, gamosepalous, valvate.**

(ii) *Corolla*—petals 5, polypetalous, sometimes slightly united at the base ; aestivation twisted.

(iii) *Androecium*—stamens many, monadelphous, the filaments of the stamens united to form a hollow tube attached to the base of the petals and enclosing the ovary and the style ; anthers reniform, **one-chambered.**

Fig. 112. Cotton. A, flowering branch ; B, a flower cut vertically ; C, the staminal column enclosing the ovary and style ; D, the free end of filament with an anther ; E, transverse section of ovary ; F, young fruit enclosed by the persistent calyx ; G, a fruit enclosed by the epicalyx ; H, capsule dehisced showing mass of cotton.

(iv) *Gynoecium*—carpels 5 to many, syncarpous ; ovary superior, with as many chambers as there are carpels ; ovules one to many in each chamber ; placentation axile ; style one, slender, passing through the staminal tube ; stigmas as many as there are carpels.

Fruit—a capsule.

Family 3. Leguminosae

The most characteristic features of the family are as follows: *leaves*—usually pinnately compound, stipulate; *gynoecium*—monocarpellary; *fruit*—a legume, from which the name of the family has been derived. Although the above characters are generally constant in all the plants of this family, variations exist in the structure of the corolla and stamens on the basis of which this big family is divided into *three* subfamilies: (*i*) Papilionaceae, (*ii*) Caesalpinieae and (*iii*) Mimoseae.

Sub-family 1. Papilionaceae

Common plants—Pea (Fig. 113), Gram, Bean, Lentil and all other pulses, Ground-nut, Indigo, Shisam or Sissoo (a timber tree), Sunn Hemp (B. Shon), *Sesbania* (B. Bakful), *Clitoria* (B. Aparajita), Atashi, Parrot tree (B. Palash), etc.

Plants—herbs, shrubs or trees.

Leaves—pinnately compound, rarely simple, (e.g., Atashi), stipulate.

Flowers—Usually in recemes, bisexual, complete, zygomorphic, perigynous.

(i) *Calyx*—sepals 5, gamosepalous.

(ii) *Corolla*—petals 5, of the petals the outermost is the largest and is called the *standard* or *vexillum*, the two lateral ones are known as the *alae* or *wings*, and the two innermost ones are the smallest and more or less united to form a boat-shaped structure called the *keel* or *carina* (papilionaceous); aestivation vexillary.

(iii) *Androecium*—stamens 10, in two bundles (diadelphous), the filaments of 9 stamens are united into one bundle, and the remaining one is free, rarely monadelphous, as in Atashi and Sunn Hemp; anthers dorsifixed.

(iv) *Gynoecium*—monocarpellary, ovary, superior, one-chambered with many ovules, placentation marginal.

Fruit (Fig. 127, 1, 2)—a legume. *Seeds*—exalbuminous.

The Pea Plant

The pea plant (Fig. 113) is a herbaceous annual with a trailing, climbing or bushy habit. The root system consists of a main tap root with many lateral branches penetrating deep down in the soil. Many nodules or tubercles are present in the root; these are induced by the attack of many soil bacteria (*Rhizobium*). These bacteria live in the nodules and there fix atmospheric nitrogen. (see roots, fig. 113).

The leaves are pinnately compound and are arranged alternately; the leaflets are oval to ovate in form with a smooth surface and are arranged in one to several pairs with the terminal leaflet and the uppermost pair or pairs modified into tendrils which serve the purpose of climbing. At the base of the petiole there are two foliaceous stipules which frequently equal the leaflets in size.

The *inflorescence* is a few-flowered raceme developing in the axil of the leaf. The flowers are mostly white or purplish in colour. For the description of the flower see description of flowers.

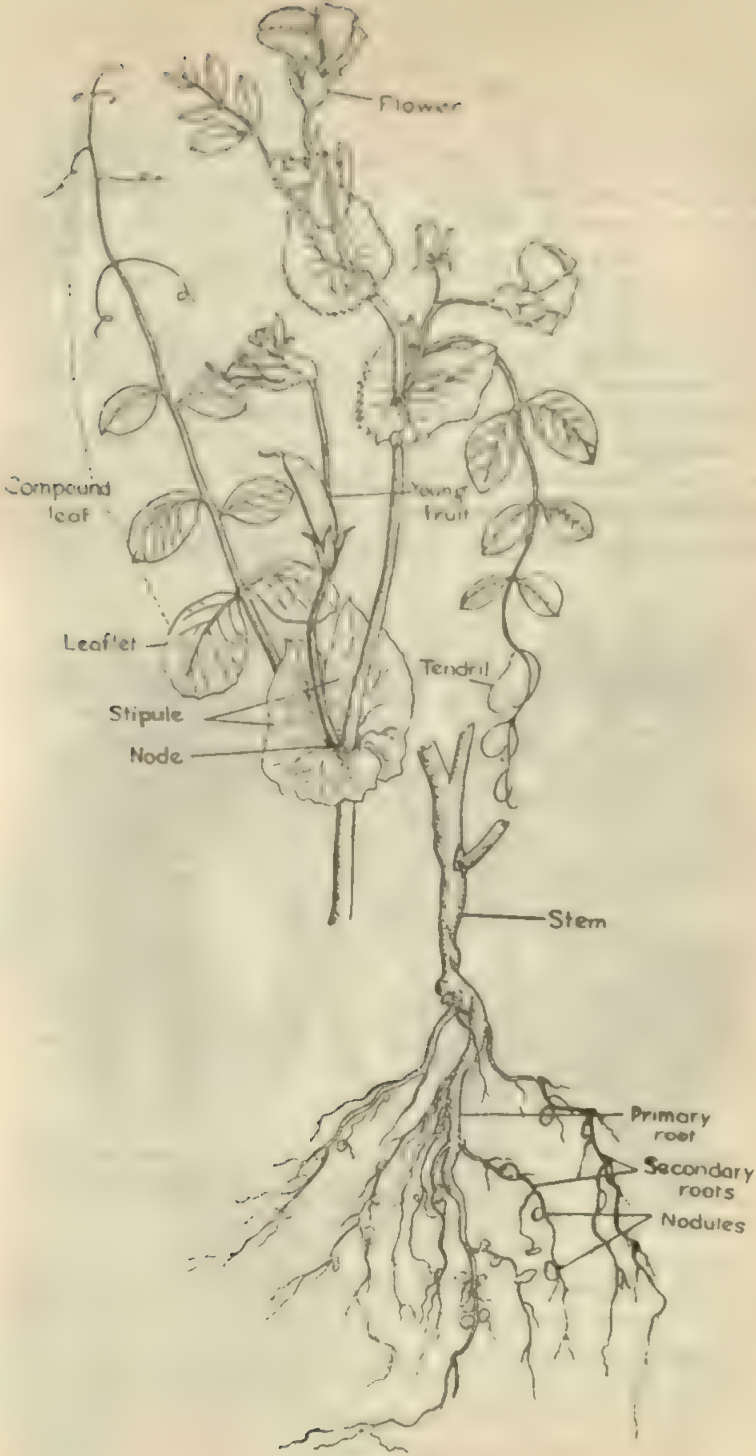


Fig. 113. Pea plant.

The *fruit* [Fig. 107, 1 and 2] is a legume or pod which when mature breaks up from the apex to the base into two parts. In the variety known as Sugar pea (B. Olanda Sunti) the pericarp remains soft and succulent and is edible. The pods of the larger varieties of pea may often reach a length of 15 cm. and a width of 5 cm.

The *seeds* are large globular with a thin seed coat (testa) and each contains an embryo consisting of two large fleshy cotyledons, a well-developed radicle and a fully differentiated plumule.

Pollination—The flowers secrete nectar. As both pollen and nectar are concealed in the keel they can be obtained only by fairly strong and intelligent insects. Humming bees are the chief agents for cross pollination. The insect alights upon the wings;

Fig. 114. *Cassia* (B. Kalkasunde). A, portion of a branch with one leaf and an axillary inflorescence; B, an opening flower; C, stamens and pistil; D, the pistil; E, transverse section of ovary; F, a fruit; G, portion of a fruit split open to show the arrangement of seeds; **H, a fruit showing dehiscence, I, a seed.**

its weight depresses both wings and keel and as a result the stigma and the anthers are forced out from the keel and rub on the lower surface of the insect's body. If the insect had previously visited a similar flower, it must have carried pollen grains from there, some of which stick to the stigma. Thus bringing about the pollination, the insect flies off with a new supply of pollen to

be used for pollinating other flowers. When the anthers come out with force some of the pollen reach the stigma of the same flower, but such pollen grains are usually self-sterile and have generally no effect.

Sub-family 2. Caesalpinieae

Common plants—Different species of *Cassia* (B Kalkasunde) (Fig. 114), Shondal, Krishnachura, Tamarind, *Bauhinia* (B Kanchan), etc.

Flowers pedicellate, bracteate, bisexual, complete, slightly irregular. *Sepals*—5, free, imbricate, *Stamens*—10 (or fewer by abortion), free.

Fruit—a more or less cylindrical or an oblong and flattened legume with many seeds.

Sub-family 3. Mimoseae

Common plants—Sensitive plant, *Acacia arabica* (B. Babla), (Fig. 115), *Albizzia* (B Shirish), etc.

Leaves—usually bipinnate, *Inflorescence*—a head or a spike.

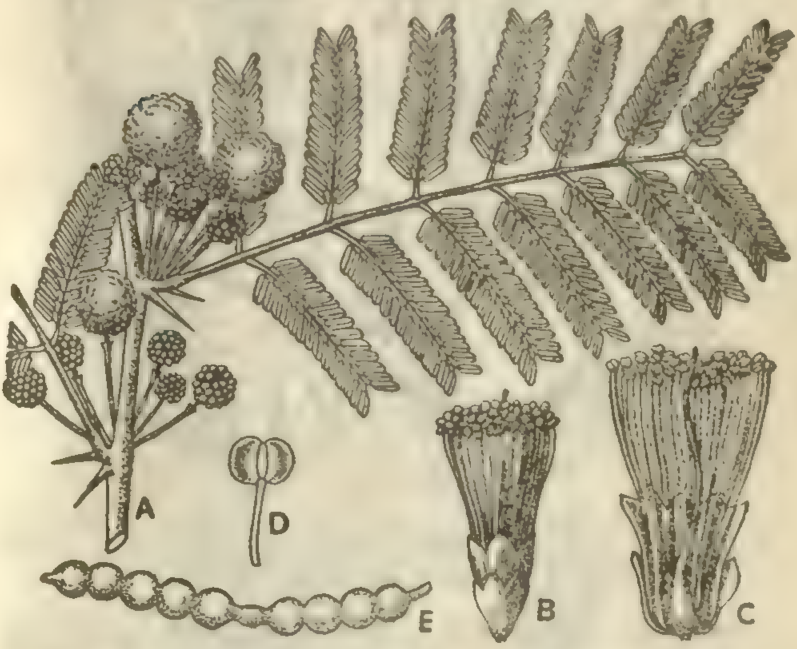


Fig. 115. *Acacia* (B. Babla). A, a portion of a branch bearing axillary inflorescences ; B, a flower ; C, the flower split open ; D, a young stamen ; E, a fruit.

Flowers —bracteate, bisexual, complete, regular. *Sepals*—4-5, gamosepalous. *Petals*—4-5, gamopetalous ; aestivation valvate. *Stamens*—4-many, free or united at the base.

Fruit—an indehiscent lomentum, septate between the seeds.

Family 4. Cucurbitaceae

Common plants—Gourd (B. Mitha Kumra), Bottle gourd (B. Lau), *Trichosanthes dioica* (B. Patol), *Trichosanthes anguina* (B. Chichinga), (B. Dhundhul or Purul), *Benincasa* (B. Chal Kumra), *Coccinia* (B. Telakucha) (Fig. 116). Cucumber, Melon, Watermelon, etc.

Plants—herbs or shrubs, climbing by means of simple or branched tendrils.

Leaves—simple, often lobed, alternate, petiolate, exstipulate, palmately-venied.

Flowers—solitary or in recemes, pedicellate, bracteate or ebracteate, regular, unisexual, colour of flowers yellow or white.

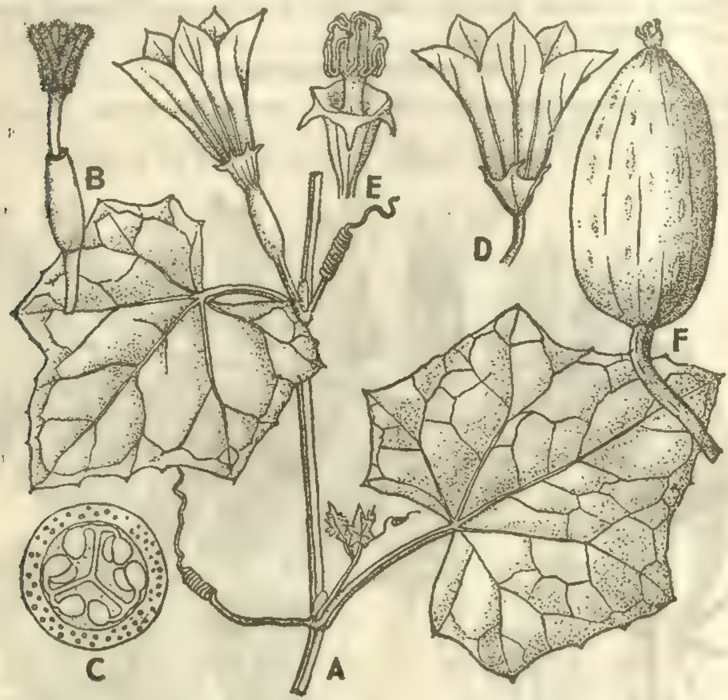


Fig. 116. *Coccinia* (B. Telakucha). A, portion of a female plant bearing a pistillate flower ; B, the pistil ; C, transverse section of ovary ; D, a staminate flower ; E, the same after removing the petals ; F, a fruit.

Male flowers—*Calyx*—sepals 5, gamosepalous, united into a tube. *Corolla*—petals 5, inserted on the calyx tube, usually united, sometimes free ; sometimes, as in *Trichosanthes*, fimbriate at the margin. *Androecium*—stamens 3, rarely 5, anthers united into a ring (syngenesious) or free, anther cells sinuous or straight, filaments free or united.

Female Flowers—*Calyx* and *corolla* as in the male flower. *Gynoecium*—carpels 3, syncarpous ; ovary inferior, unilocular, or falsely trilocular, with many ovules ; placentation parietal.

Fruit—a pepo or berry, usually indehiscent, sometimes dehiscent by valves, as in *Momordica* (B. Uchchhe), or by a big pore, as in *Luffa* (B. Dhundhul). *Seeds*—many, compressed.

Fig. 117. A, a flowering branch of Sunflower ; B, a disc floret ; C, a ray floret ; D, a disc floret split open to show the androecium ; E, the stamens united by their anthers ; F, the syngenesious androecium split open ; G. Longitudinal section of ovary showing only one basal ovule.

SUB-CLASS II. GAMOPETALAE

Family 5. Compositae

Common plants—Sunflower (Fig. 117), Marigold, Chrysanthemum (B. Chandramallika), Dahlia, Zinnia, Cosmos, Lettuce, *Enhydra* (B. Hinche), etc.

Plants—herbs, rarely shrubs.

Leaves—simple, rarely compound, alternate or opposite, exstipulate.

Inflorescence—capitulum surrounded by an involucre of bracts. The flowers in the capitulum may be (i) all tubular or (ii) all ligulate; or (iii) more usually the central flowers are tubular called the *disc florets* and the marginal ones ligulate called the *ray florets*.

Fig. 118. A, a flowering branch of Brinjal; B, an open flower; C, corolla split open showing the epipetalous stamens; D, E, stamens in different positions showing the apical pores of anthers; F, flower after removal of corolla and androecium showing the gamosepalous calyx; G, gynoecium showing the ovary, style and bilobed stigma; H, transverse section of ovary; I, Floral diagram.

Disc florets—sessile, bracteate (bract scaly), regular, bisexual, epigynous. *Calyx*—modified into scaly or hairy structures forming what is known as the pappus. *Corolla*—petals 5, gamopetalous, tubular. *Stamens*—5, epipetalous, filaments free, but the anthers united (syngenesious). *Gynoecium*—bicarpellary, syncarpous; ovary inferior, 1-chambered with only one ovule; placentation basal; style 1, stigmas 2.

Ray florets—sessile, bracteate, irregular, ligulate, unisexual (female) or neuter, epigynous. *Calyx* as in disc florets. *Corolla*—petals 5, gamopetalous, ligulate. *Gynoecium* as in the disc florets.

Fruit—a cypsela.

Family 6. Solanaceae

Common plants—Potato, Brinjal (Fig. 118), Tomato, Chillie (B. Lanka), Indian Gooseberry (B. Tepari), Tobacco, Queen of the night (B. Hasnahana), Thorn apple (B. Dhutura), etc.

Plants—herbs or shrubs.

Leaves—simple or compound, alternate, exstipulate ; in some cases stems and leaves are covered with prickles.

Flowers (Fig. 118)—solitary or in cymose inflorescence, pedicellate, bisexual, complete, regular, hypogynous.

(i) *Calyx*—sepals 5, gamosepalous, usually persistent, sometimes accrescent.

(ii) *Corolla*—petals 5, gamopetalous, rotate, bell-shaped or funnel-shaped.

(iii) *Androecium*—stamens 5, free, epipetalous ; anthers basifixed, opening by longitudinal slits or by apical pores.

(iv) *Gynoecium*—bicarpellary, syncarpous ; ovary superior, 2-chambered, often becoming 4-5-chambered by the development of false partition walls ; ovules many in each chamber, placentation axile ; style simple, elongated ; stigma capitate or 2-lobed.

Fruit—a berry or capsule.

SUB-CLASS III. INCOMPLETAE

Family 7. Euphorbiaceae

Common plants—Castor-oil plant, *Poinsettia* (B. Lalpata), *Acalypha* (B. Mukta Jhuri), *Trewia* (B. Pituli), *Pedilanthus* (B. Rangchita), Amla or Amlaki, Garden Crotons with variegated leaves, *Croton bonplandianum* (a very common weed), many species of *Euphorbia*, *etc.*

Plants—herbs, shrubs or trees, often with milky latex.

Leaves—simple, alternate or opposite, entire or palmately lobed, stipulate.

Inflorescence—(Fig. 119) very varied, racemose, or cymose.

Flowers—small, bracteate, regular, always unisexual (monoecious or dioecious), hypogynous.

Perianth—green or coloured, in some flowers the perianth consists of both calyx and corolla, in others there is no corolla ; sometimes both are absent.

Androecium (in male flowers)—there may be only a single stamen, as in *Euphorbia ;* usually stamens few to many ; in Castor-oil plant the stamens become very numerous due to repeated branching of the filaments.

Gynoecium (in female flowers)—tricarpellary, syncarpous, ovary superior; 3-lobed and 3-chambered with 1 or 2 ovules in each chamber; styles 3; stigmas 6.

Fruit—a capsule. *Seeds*—albuminous, often with an aril.

Fig. 119. A, part of a castor plant with one leaf and an inflorescence; B, a male flower; C, a branched stamen; D, a female flower; E, Transverse section of 3-chambered ovary with one ovule in each chamber; F, longitudinal section of ovary; G, a fruit; H, seed with aril.

FAMILIES OF MONOCOTYLEDONS

SUB-CLASS I. PETALOIDEAE

Family 1. Liliaceae

Common plants—*Asparagus* (B. Satamuli), *Smilax* (B. Kumarika), Onion (Fig. 120), Garlic, *Aloe* (B. Ghritakumari), *Sanseviera* (B. Murga), *Yucca*, etc.

Plants —herbs, rarely shrubs. Stems-various ; they include bulbs, corms and tubers and also aerial forms which may be simple (*Yucca*) or branched (*Asparagus*).

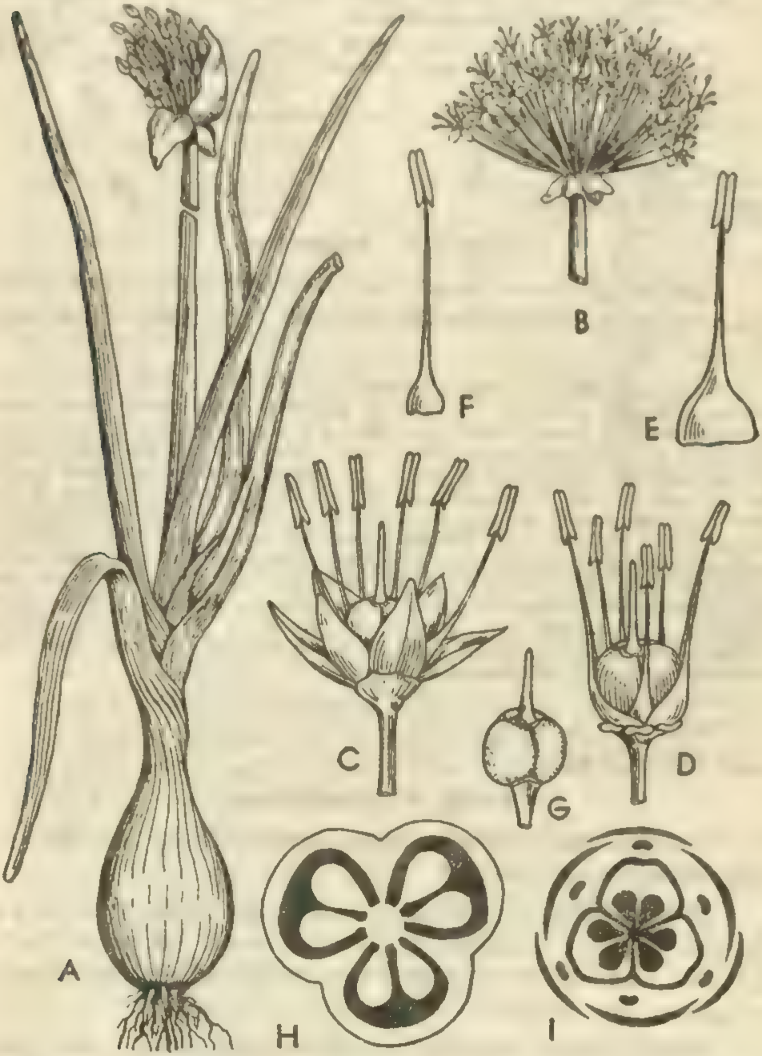


Fig. 120. A, onion plant ; B, inflorescence ; C, a flower ; D, flower after removal of perianth leaves ; E, F, stamens ; G, gynoecium, H, transverse section of ovary ; I, floral diagram.

Leav s —radical or cauline, or both ; radical leaves are usually large and sheathing at their bases. Venation usually parallel, reticulate in *Smilax*.

Inflorescence —various, but usually racemose.

Flowers –bracteate, bisexual, regular, hypogynous.

Perianth—petaloid, 6 segments in two whorls, united (gamophyllous), imbricate.

Androecium—stamens 6 in two whorls, attached to the perianth leaves by their filaments (epiphyllous), free.

Gynoecium—tricarpellary, syncarpous, ovary superior, 3-chambered with two or more ovules in each chamber; placentation axile; style 1, stigmas usually 3.

Fruits—a capsule or a berry. *Seeds*—albuminous.

SUB-CLASS II. SPADICIFLORAE

Family 2. Palmaceae

Common plants—Coconut palm, Palmyra palm, Date palm, Betel-nut palm, Nipa palm (B. Golpata), Sago palm, Cane palm (B. Bet), etc.

The palms generally attain the size of trees. Their stems are usually unbranched and generally of uniform diameter throughout. The *leaves* usually attain a gigantic size and form a terminal crown. They appear pinnately or palmately compound in many cases, but are definitely simple. In the bud the young leaf is simple, but as it grows older, lobes appear in the leaf by the disorganisation of definite portions of tissues of the leaf and subsequent tearing along these lines. *Inflorescence*—axillary, when young enclosed by a massive sheathing bract, the *spathe*. *Flowers* unisexual, usually monoecious, sometimes dioecious, e.g., Palmyra palm. *Perianth*—6, in two whorls, sepaloid, persistent. *Stamens*—6, may be also 3. *Gynoecium*—tricarpellary, usually syncarpous, sometimes free, ovary superior, 3-chambered, but usually in course of development becomes 1-chambered. Fruit—a berry (e.g., Date) or a drupe generally containing a single seed with considerable endosperm.

SUB-CLASS III. GLUMIFLORAE

Family 3. Graminaceae

Common plants—Paddy, wheat, Barley, Maize, Oat, Bamboo, Sugarcane, Grasses, etc.

Plants—annual or perennial herbs, rarely shrubs or trees, e.g., Bamboos; stems conspicuously jointed; usually hollow in the internodes and solid at the nodes; sometimes solid throughout, as in Sugarcane and Maize.

Leaves—simple, alternate, distichous (two ranked), with sheathing leaf-bases which split on the side opposite the leaf-blades; at the junction of the sheath and the blade there is a ligule; leaf blades usually long and narrow; margins entire; venation parallel.

Inflorescence—a spike or a panicle composed of partial inflorescences, the *spikelets* [Fig. 121]. A spikelet may consist of a single flower, or of several with usually a rudimentary one

at the apex. The spikelet consists of an axis bearing flowers alternately in two rows. At the base of each spikelet are found two membranous sterile bracts placed alternately. These are called the *glumes.* Above the glumes there may be a single flower or more, usually there are two or more flowers arranged in two rows on the axis of the spikelet. Each flower is enveloped in two bracts, which often closely resemble the glumes. The lower bract in the axil of which the flower is developed, is called the *flowering glume* or *lemma ;* the upper bract attached to the axis of the flower just above the attachment of the flowering glume, is called the *palea.*

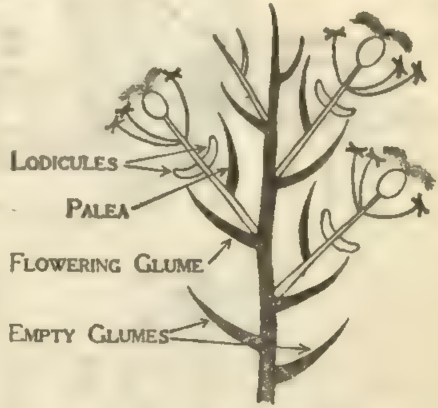


Fig. 121. Diagram of a spikelet.

Flowers—usually bisexual, sometimes unisexual (monoecious). *Perianth* is represented by two small colourless scales called *lodicules* placed above the flowering glume and the palea. Sometimes three lodicules are present ; occasionally they are absent. *Stamens* usually 3, sometimes 6 (as in Paddy and Bamboo) with long flexible filaments and versatile anthers. *Gynoecium* monocarpellary, ovary superior, one-chambered, with a single ovule ; styles 1 or 2 ; stigmas 2, feathery.

Fruit—a caryopsis ; in it the pericarp is closely united with the seed coat. In some plants, particularly in Paddy, Barley and Oat the flowering glume and palea also become adherent to the fruit completely enclosing it. The single *seed* is albuminous and contains a small embryo. The solitary cotyledon is transformed into an absorptive organ called the *scutellum.*

Rice plant [Figs. 121-123] The plant produces one of the most important cereals and is cultivated throughout the warmer parts of the world. The rice grain forms the staple food of the population of many parts of the globe. Plant—an annual grass growing to a height of 2 to 5 ft. Stem hollow, cylindrical. Roots —fibrous. The plant has an elaborate root system consisting of many adventitious roots developed from the lowest node. The

primary root (Fig. 122, PR) usually decays. Leaves—long, narrow, flat, with a sheathing base; venation parallel, a prominent ligule

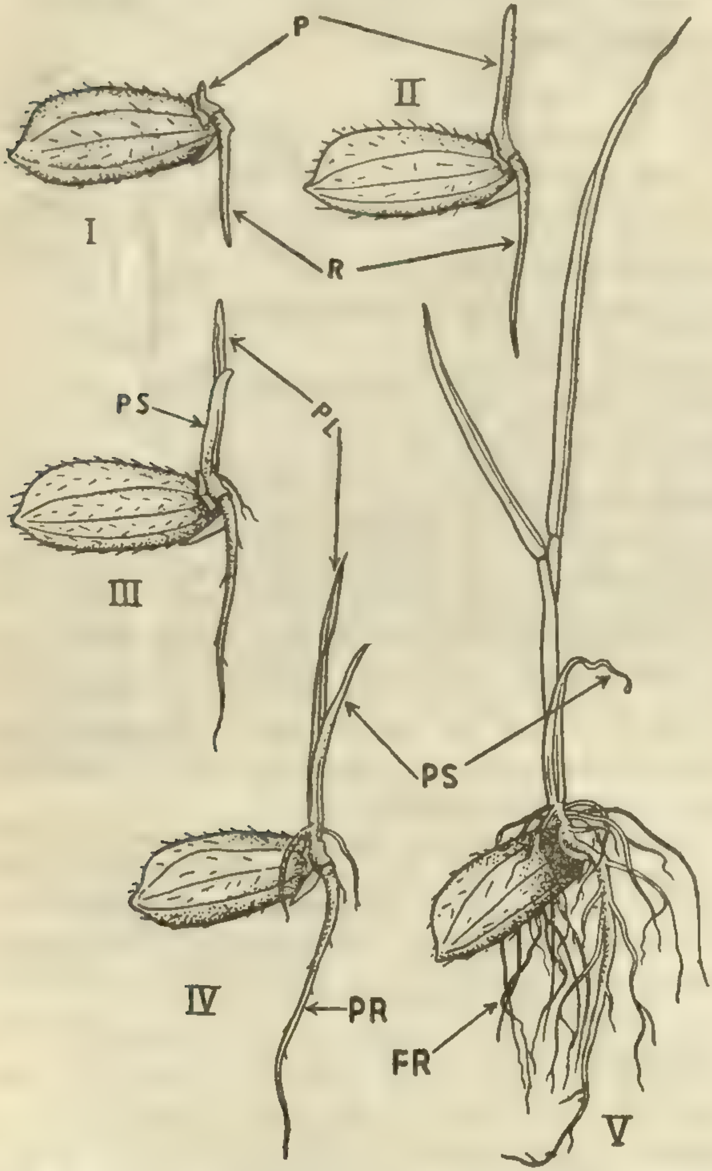


Fig. 122. Rice grain showing different stages of germination. P, plumule; PR, primary root; PS, plumule sheath; PL, plumule enclosed by 1st leaf; FR, the primary root of the seedling soon decays and is replaced by many adventitious roots. (a few such roots are seen in fig. V).

is present at the junction of the blade and the sheath. *Inflorescence*—a panicle composed of a number of fine branches, each

Fig. 123. A, panicle of rice with one leaf; B, a spikelet; C, spikelet split open showing the different parts.

terminating in a single spikelet. *Spikelet*-one-flowered, loosely arranged on the branches of the panicle. At the base of each spikelet there are 2 small membranous persistent bracts called the empty glumes; above them lies the single flower which is enveloped in two larger bracts. The lower one (in the axil of which the flower develops) is the *flowering glume* which may or may not have at its apex a narrow elongated outgrowth called the awn; the upper one inserted a little above the flowering glume, is called the *palea*. *Perianth*-represented by 2 scales called *lodicules*. *Androecium*-stamens 6, free, anthers linear, versatile. *Gynoecium*-monocarpellary, ovary superior, unilocular with only one ovule; styles 2, short; stigmas 2, feathery. *Fruit*-a caryopsis; the flowering glume and palea become adherent to the fruit completely enclosing it. The single seed is albuminous and contains a small embryo. The solitary cotyledon is transformed into an absorptive organ called the scutellum.

Fig. 124. Maize plant with a terminal panicle of male spikelets and two cobs, each in the axil of a leaf.

Grains of rice are removed from the inflorescence usually by threshing and the grains are stored in the 'paddy' condition. The grains are husked before they are to be used for various purposes. The rice grain has different textures, colours, sizes and shapes. The grain colour is often used to determine the quality and also the variety.

Maize Plants

The Maize plant (Fig. 124) is a herbaceous monocotyledonous annual with a solid jointed stem. The stem is fairly stout and may attain a height of 12 to 15 feet and is never branched.

Fig. 125. Lower portion of a maize plant showing adventitious roots.

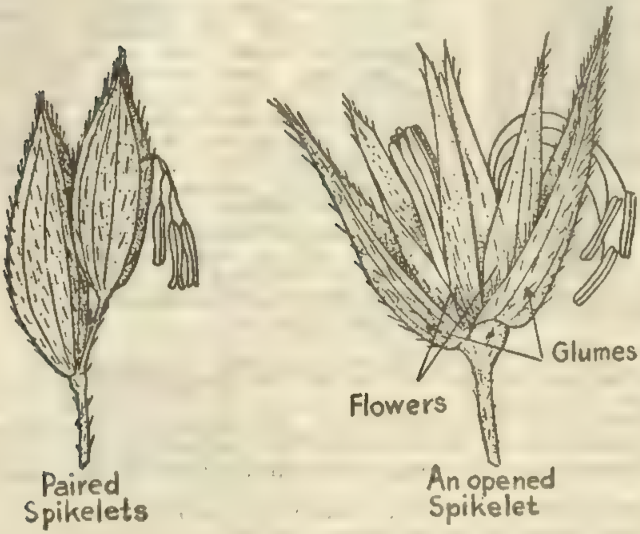


Fig. 126. Spikelets of maize.

The plant has an extensive root system (Fig. 125) consisting of several whorls of adventitious roots developing from the lower nodes. Most of the roots penetrate deeply into the soil. The primary root usually decays.

The *leaves* are very well developed and consist of two parts, the *sheath* and the *blade*. The sheath surrounds the internode for some distance above the node from which it develops. The blade is long and flat with entire margin and parallel venation. At the junction of the sheath and blade there is a collar-like ligule. The leaves are arranged alternately in two rows on the stem.

Fig. 127. A cob, i.e., the pistillate inflorescence of Maize.

The maize plant is monoecious producing staminate (male) and pistillate (female) flowers in the same plant. The two kinds of flowers develop in two kinds of spikelets arranged on separate inflorescences.

The *staminate inflorescence* develops at a large number of spikelets. The spikelets the apex of the stem and is a panicle bearing develop in pairs; one of the spikelets is provided with a short stalk, the other is sessile (Fig. 126, left). Each spikelet is 2-flowered (Fig. 126, right). At the base of each spikelet there are two sterile glumes. The two flowers are arranged alternately on the short axis of the spikelet. Each *flower* is enclosed by two bracts—the *flowering glume* or *lemma* and the *palea*. *Perianth leaves* are represented by two minute fleshy scales called lodicules. *Stamens* 3; anthers linear and pendulous.

The *pistillate inflorescence* (Fig. 127) is a spadix (also known as a *cob*) and arises in the axil of a lower leaf. Usually a few such inflorescences are developed in a plant. Each spadix (cob) is enclosed in a number of leafy bracts. The spikelets are densely crowded in several rows on the fleshy axis of the cob. Each *spikelet* is two-flowered and has at its base two sterile glumes. The lower flower is usually abortive and the upper fertile. Each of the *flowers* is enclosed by the flowering glume and the palea and has two lodicules. *Gynoecium* (present only in the fertile flower) monocarpellary; ovary ovoid, one-chambered containing a single ovule; style 1, long, somewhat flattened; stigma 1, very long, and hairy. The very long thread-like silky stigmas come out from the top of the cob.

The *fruit* or the maize grain is a caryopsis; a large number of the grains are arranged in rows on the cob and constitute the *ear* of maize. The seed is albuminous.

Pollination is brought about by wind. The pollen grains are discharged in large quantities from the anthers of the staminate flowers. Some of them are received by the long hairy stigmas which protrude from the cobs.

Cultivation and uses—There are many varieties of Maize, all of which are cultivated during the rainy season. High open land where no water-logging takes place, is suitable for growing Maize. The Maize grains, both green and dry are extensively used as an article of food. The mature grains supply an important article of diet to the poor people of Bihar. In America the grains are particularly utilised for the fattening of animals to be slaughtered.

TISSUE SYSTEM

An aggregate of similar cells is called a tissue. A plant tissue is an aggregate of structurally similar cells with a common function. The sporophyte of a multicellular vascular plant begins with a single cell, the zygote. By repeated divisions the zygote develops a group of undifferentiated tissue which constitutes the meristematic tissue. The undifferentiated meristematic tissue is soon differentiated into the apical meristems (promeristem) of the root and the stem. From these apical meristems three principle systems of primordial tissues, viz., the protoderm, procambium and ground meristem are developed. From these primordial tissues the three principal tissue systems, namely, (i) the epidermal tissue system, (ii) the fascicular or conducting tissue system composed of the xylem and phloem tissues and (iii) the fundamental or ground tissue system are developed. (see Fig. 43, Part I)

Promeristem

Protoderm	Procambium	Ground meristem
Epidermis or the epidermal tissue system.	Vascular or fascicular tissue system consisting of the conducting strands of xylem and phloem.	Fundamental or Ground tissue system consisting of cortex, pith or medulla and medullary rays.

A tissue system is composed of one or a few kinds of tissues which perform a common function. All the tissue found in plants may be grouped into *three* systems: (*I*) *Epidermal tissue system*; (*II*) *Ground* or *fundamental tissue system* and (*III*) *Vascular* or *conducting tissue system.*

I. Epidermal tissue system—This consists of the outer-most layer of young roots, young stems, petioles, leaves, and floral axes and is also known as the *epidermis*. Usually it consists of a single layer of cells, but sometimes the epidermis is composed of a few layers, as in the roots of Orchids and in the leaves of Banyan and India Rubber plants. Epidermal cells are usually of irregular shapes [Fig. 128], but in transverse section they appear as more or less rectangular. They are compactly arranged without having any intercellular spaces in between them. They are living but

usually do not have chloroplasts. Chloroplasts are present in the epidermal cells of shade loving and aquatic plants. The epidermis often develops hairs on its surface. In the case of roots the hairs are always unicellular. Epidermal hairs of stem may be unicellular or multicellular. The outer walls of the epidermal cells of aerial parts of plants are often very much thickened and cutinised and form a definite layer known as the *cuticle*. The main function of the epidermis is to protect the internal parts of the plant body and to prevent excessive evaporation of water.

Stomata [Figs. 128, 129, 130]—Stomata (sing. Stoma) are minute openings found in the epidermis of the aerial green parts of plants. Each stoma consists of a passage or pore surrounded by two specialised epidermal cells called *guard cells.* The entire structure, including the guard cells and the pore which they sur-

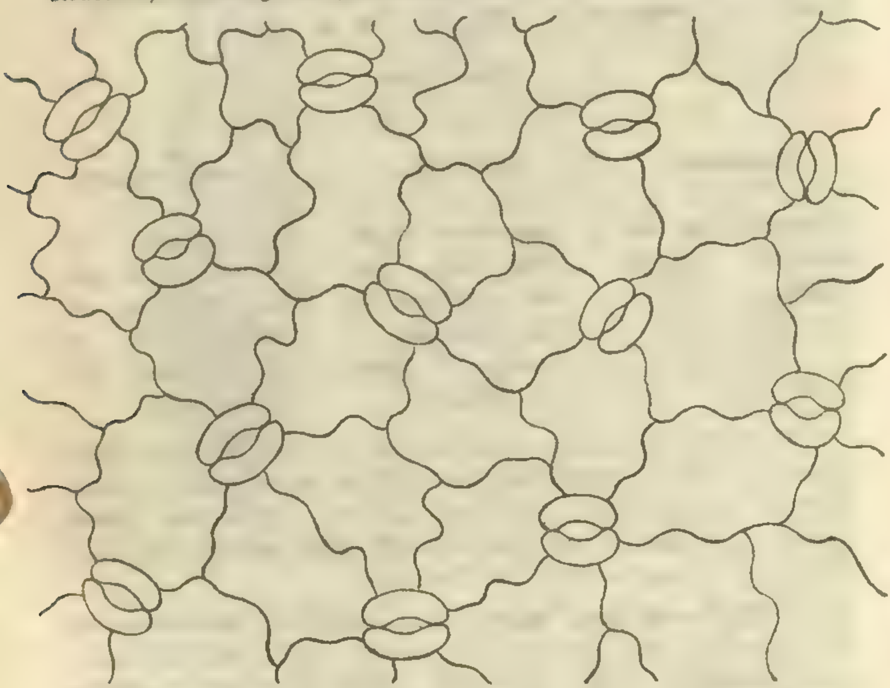


Fig. 128. Surface view of the lower epidermis of a typical dicotyledon leaf showing many stomata.

round, constitutes the *stoma* or *stomatal apparatus.* The pore leads below the epidermis into a large intercellular space called the substomatal air-chamber [Fig. 130]. This chamber is in communication with the air-filled intercellular spaces of the parenchyma.

The guard cells are more or less semilunar in shape and contain chloroplasts besides cytoplasm and nucleus. Stomata usually remain open during day-time, but are closed at night. The opening and closing of the apertures of the stomata are regulated by the guard cells.

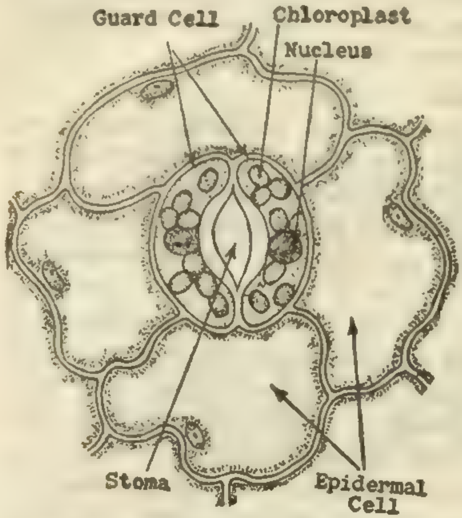


Fig. 129. A small portion of the epidermis shown in fig. 128 much magnified showing the details of a stoma.

Formation of a stoma—A stoma is formed by the vertical division of a young epidermal cell into two. The common wall splits in such a way that an opening is formed between the two cells. This opening is the aperture of the stoma and the two cells form the guard cells.

Functions of stomata — Stomata are mainly meant for the interchange of gases between the internal tissues and the external atmosphere in the process of respiration and photosynthesis (manufacture of carbohydrate food products). They are also concerned with the evaporation of excess water from the leaves and other exposed parts of the plant.

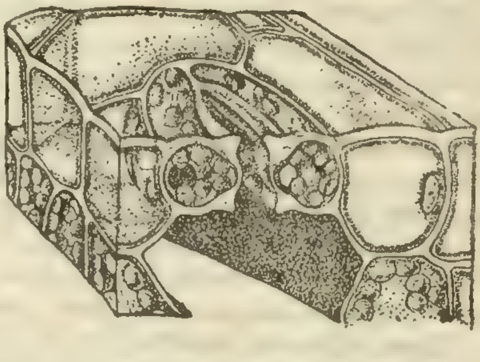


Fig. 130. Diagrammatic view of a typical stoma and the adjoining epidermal cells as seen in surface view and in transverse section. The sub-stomatal air-chamber is seen below the stoma.

Distribution of stomata—Stomata are found in all the exposed

green parts of plants. In dorsiventral leaves they are especially abundant on the lower surface in isobilateral leaves they are equally distributed on both the surfaces; in floating aquatic leaves they are present only on the upper surface. They can never be found in the roots and submerged parts of plants.

II. Ground Tissue System

This system forms the main bulk of the young roots, young stems, leaves, flowers and fruits and consists of different kinds of tissues, but chiefly of parenchyma. In the leaves this system is generally made up of parenchyma and is called the *mesophyll.*

The central cylinder of the stem and root occupied by the vascular bundles is known as the *stele.* The tissues lying outside the stele or central cylinder are called the extra-stelar ground tissues and those lying within the stele are called the intra-stelar ground tissues. The extra-stelar ground tissues form what is known as the *cortex* which is usually distinguished into *hypodermis, parenchyma* and *starch sheath* or *endodermis,* and the intra-stelar ground tissues are marked out into the *pericycle, pith* or *medulla* and the *pith rays* or *medullary rays.* All these different kinds of tissues will be described along with the structure of stems, roots and leaves.

III. Vascular Tissue System

This is a complex system consisting chiefly of phloem and xylem constituting what are known as the *vascular bundles.* The vascular bundles of dicotyledon stems have an additional tissue called the cambium between the phloem and the xylem. The bundles are usually found within the stele, but their arrangement usually varies in the different organs of the plant body as also in different kinds of plants. The vascular tissues are used for the conduction of water and raw food materials from the roots to the leaves and prepared food from the leaves to the different growing regions as well as to the storage regions, that is, places in the plant body where food is stored for future use. Further, these tissues give strength and support to the plant body.

Types of vascular bundles [Fig. 131]—In the vascular tissues phloem and xylem are not usually found separately so a vascular bundle usually consists of both these types of tissues. In the case of roots, however, xylem and phloem are not grouped together. According to the different positions of xylem and phloem, vascular bundles may be of the following types:—

(i) Collateral—A vascular bundle is said to be collateral when

the xylem and the phloem lie side by side in the same radius, the phloem lying on the outer side of the xylem. In dicotyledon stems an additional meristematic tissue called the *cambium* is found between the phloem and the xylem such a bundle is called an

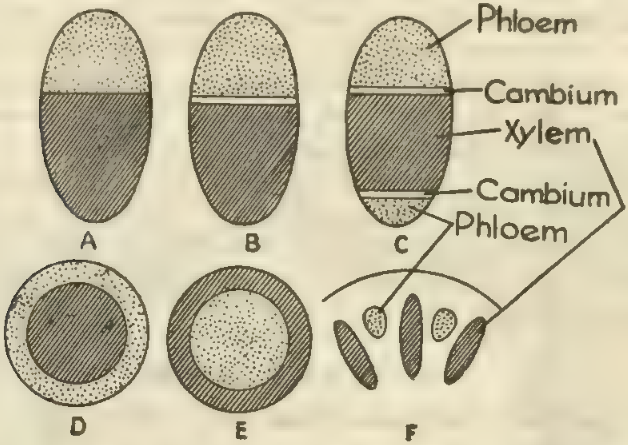


Fig. 131. Types of vascular bundles. A, closed collateral ; B, open collateral ; C, bicollateral ; D & E, concentric bundles ; in D, xylem is surrounded by phloem and in E, phloem is surrounded by xylem ; F, radial. The xylem is shaded by lines, the phloem stippled and the cambium unshaded.

open collateral bundle [Fig. 133]. In the monocotyledon stems no cambium is present, and the bundle is called *closed collateral* [Fig. 135].

(ii) Bicollateral—In bicollateral bundles the xylem forms one mass in the middle and the phloem is found in two different masses both inside and outside xylem. Bicollateral bundles are found in the stems of Gourd, Cucumber, etc. [Fig. 134].

In a typical bicollateral bundle the tissues are arranged in the following order : (i) outer phloem, (ii) outer cambium, (iii) xylem, (iv) inner cambium and (v) inner phloem.

(iii) Concentric—When one type of tissue surrounds the other. In concentric bundles found in the stems of Fern, the phloem surrounds the xylem [Fig. 131D] ; and in *Dracaena*, a monocotyledon, the xylem surrounds the phloem [Fig. 131E].

(iv) Radial—In this case strands of xylem and of phloem are separated from one another and lie alternately on different radii of an axis. These strands form the radial bundles. They are found only in the roots [Figs. 136 & 137].

THE PRIMARY BODY

The growing point of the stem and of the root in all the different kinds of plants consists of a mass of meristematic cells.

The differentiation of the apical meristems into the different primary permanent tissue is usually completed before the end of the first-year's growth. All the primary permanent tissues include: (i) the *epidermis*, (ii) the *vascular tissues* (also called the *vascular bundles*), and the extra and intra-stelar ground tissues, viz., (iii) the *cortex* including the *hypodermis* and the *starch sheath* or *endodermis*, (iv) the *pericycle*, which is always present in a root but may or may not be present in a stem, (v) the *pith* or *medulla* and (vi) the *pith rays* or *medullary rays*. All these tissues can be more or less clearly found in the young stems, young roots and leaves.

STRUCTURE OF STEMS

Young Sunflower (Dicotyledon) Stem [Figs. 132 & 133]

In a thin transverse section of a young Sunflower stem the following tissues are seen to be arranged from the periphery to the centre.

1. Epidermis—The epidermis consists of a single superficial layer of somewhat flattened living cells, each with a lining layer of cytoplasm. Chloroplasts are usually absent in these cells. The outer wall of each cell is thickened and covered externally by a thin film of cuticle. The epidermis possesses a few stomata; a number of multicellular hairs develop from the surface of the epidermis. The epidermis thus forms a protective skin.

2. Cortex—Beneath the epidermis is a band of tissue called the cortex. The cortex is differentiated into three regions: (i) a few layers of collenchyma, (ii) a few layers of parenchyma and (iii) the starch sheath.

(i) The **collenchyma** is found just below the epidermis and forms the outermost layer of the cortex which is often called the *hypodermis*. The collenchyma cells are living and contain chloroplasts. The cells are thickened only at the corners with alternating layers of cellulose and pectin.

(ii) Parenchyma—The collenchyma passes over gradually to a few layers of parenchyma cells. These cells are large, thin-walled and have triangular intercellular spaces; they are living and have a lining layer of protoplasm. In the parenchyma of the cortex there are some secretory canals (*resin-ducts*), each surrounded by

a layer of small cells which are conspicuous by their abundant protoplasmic contents.

(iii) The **Starch sheath** consists of a single layer of barrel-shaped cells which fit closely together without having any inter-cellular spaces between them. The cells are thin-walled and charac-

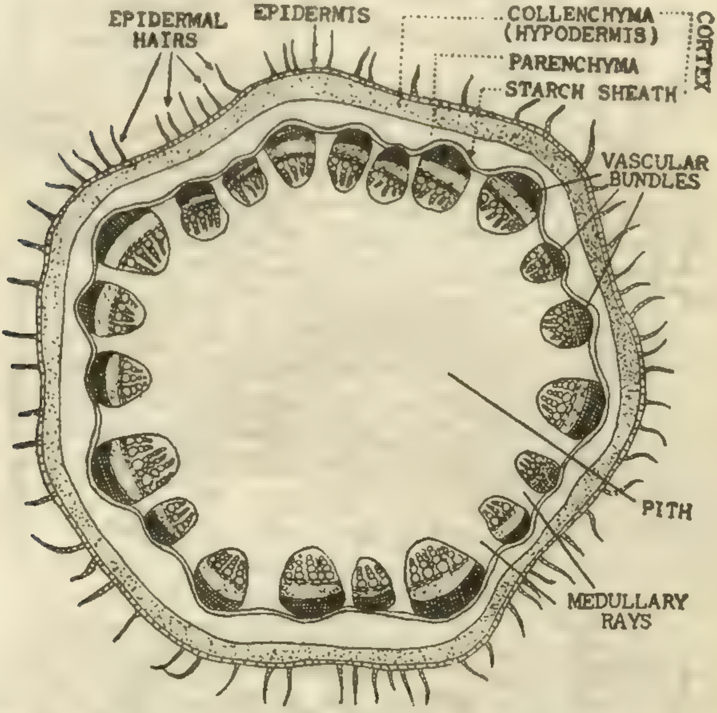


Fig. 132. Transverse section of a young Sunflower stem showing the plan of arrangement of the different tissues.

terised by the presence of starch grains. The starch sheath forms the innermost layer of the cortex and delimits the cortex from the internal tissues which together form the stele.

[The *stele* is the central cylinder of the stem comprising the vascular tissues (vascular bundles) together with the tissues that envelope them, the central parenchyma cells forming what is known as the pith or medulla, and the parenchyma cells lying between the vascular bundles (pith rays or medullary rays).]

3. Vascular bundles—The vascular bundles are about 20 to 25 in number and are arranged in a ring. Each vascular bundle is roughly oval in outline, and is collateral and open. Each bundle

is capped by a patch of sclerenchyma fibres which lie just below the starch sheath. These sclerenchyma fibres form what is known as the *hard-bast* or *bundle cap*. A bundle is composed of (i) *phloem*, (ii) *cambium* and (iii) *xylem*.

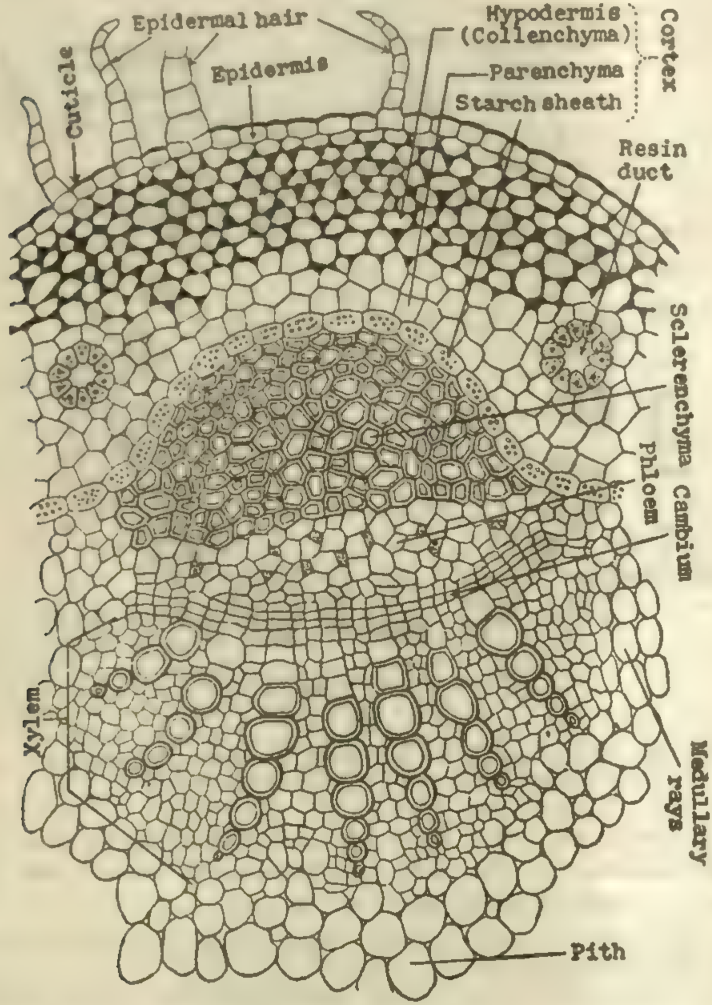


Fig. 133. Portion of a transverse section of a young Sunflower stem (highly magnified).

(i) the *phloem* or bast lies towards the periphery and is a soft tissue whose cells have cellulose walls and protoplasmic contents. The phloem is composed of *sieve tubes, companion cells*

and *phloem parenchyma*. The sieve tubes are elongated elements with perforated end-walls and a lining layer of cytoplasm. Associated with each sieve tube is found an elongated cell, the companion cell, which is conspicuous by its dense protoplasmic contents.

(ii) The *cambium* consists of a number of thin-walled meristematic cells showing active division and lies between the xylem and the phloem. The cambium cells are considerably elongated in the direction of the long axis of the stem and have pointed ends, but in transverse section they are more or less rectangular in outline. The cells of the cambium are arranged in radial rows and develop xylem on their inner side and phloem on the outer side.

(iii) The *xylem* or *wood* is found towards the centre of the stem and consists of (i) *vessels*, (ii) *tracheids*, (iii) *xylem* or *wood fibres* and (iv) *xylem* or *wood parenchyma*. (i) The most important constituents of the xylem are the vessels which are thick-walled elements. The vessels towards the pith are smaller and have annular and spiral thickenings; they constitute the *protoxylem* or the first formed xylem. The larger vessels forms the *metaxylem* and have reticulate, scalariform and pitted thickenings. (ii) Along with the vessels a number of border-pitted tracheids are found in the xylem. In transverse sections the tracheids can hardly be distinguished from the wood fibres. (iii) Wood fibres are thick-walled elongated cells, which appear polygonal in transverse section. (iv) Wood parenchyma consists of living parenchyma cells found near the protoxylem.

4. **Pith or medulla** is situated in the centre of the stem inside the vascular bundles and is made up of large parenchyma cells with numerous intercellular spaces. In Sunflower (and in all herbaceous stems) the pith is very extensive.

5. **Pith rays or medullary rays** consist of wide strips of parenchyma lying between the vascular bundles and extending from the pith to the cortex.

Young Gourd (Dicotyledon) Stem [Fig. 134]

The structure of the stem of Gourd presents some interesting features. The stem is wavy in outline having ridges and furrows. There are five ridges and five furrows alternating one with the other. The cortex is narrow and the stele is fairly broad. There is a conspicuous band of sclerenchyma which usually forms a complete ring. There are usually 10 vascular bundles arranged in two rings, of which the 5 smaller ones lying towards the peri-

phery alternate with 5 inner larger bundles. The pith of the stem is represented by a hollow cavity.

1. Epidermis—The epidermis consists of a single layer of cells. A large number of elongated multicellular hairs are present on the epidermis.

2. Cortex—The cortex is comparatively narrow and is differentiated into (i) *collenchyma* (hypodermis), (ii) 2-3 layers of *parenchyma* containing chloroplasts, and (iii) *starch sheath*, a single layer of cells containing starch grains. Opposite the ridges the collenchyma consists of several layers of living cells, thickened at the corners; it gradually thins out towards the furrows. In the furrows the collenchyma is interrupted here and there by parenchyma cells containing abundant chloroplasts.

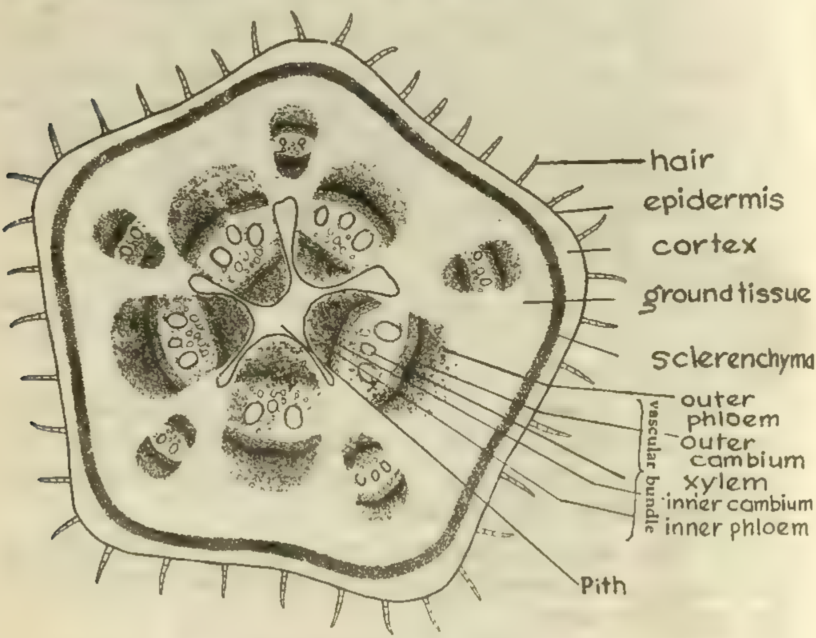


Fig. 134. Transverse section of a young Gourd stem showing the plan of arrangement of the different tissues.

3. Pericycle—It consists of a continuous band of 3-5 layers of sclerenchyma cells.

4. Ground tissues—It consists of a thick zone of thin-walled parenchyma in which the vascular bundles are embedded. It extends from below the sclerenchyma to the pith cavity.

5. Vascular bundles—They are usually 10 in number and are arranged in 2 rings. The bundles in the outer ring are smaller and stand opposite the ridges. The bundles are bicollateral, there being two patches of phloem on the two sides of the xylem; there are also two strips of cambium. The order of arrangement of the tissues in the bundles is: (i) *outer phloem*, consisting of large sieve tubes, companion cells and phloem parenchyma; (ii) *outer cambium* consisting of several layers of meristematic cells appearing brick-shaped in transverse section; (iii) *xylem* consisting of large pitted vessels which form the *metaxylem* and narrow vessels towards the inner side forming the *protoxylem*. In the xylem there are a few tracheids, some wood fibres and some parenchyma; (iv) *inner cambium*—not so well developed as the outer cambium; and (v) *inner phloem*—resembling the outer phloem in structure and in transverse section forming a crescent-shaped patch on the inner side of the xylem.

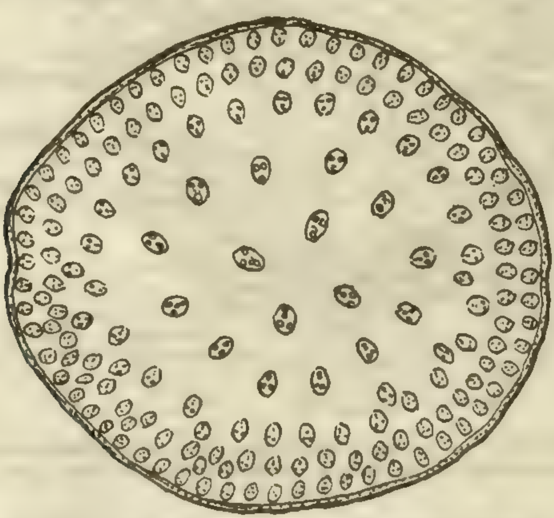


Fig. 135. Transverse section of maize stem showing the scattered vascular bundles.

6. Pith—The parenchymatous cells in the pith are disorganised early and so the pith is represented by a big hollow cavity.

Stem of Maize (Monocotyledon) [Figs. 135, 136]

In a transverse section of an internode the following tissues may be observed:

1. Epidermis—This consists of a single layer of cells covering

externally the internal tissues. A thick cuticle is formed on the outer surface of the epidermis; and a number of stomata are found here and there.

2. **Hypodermis**—This is composed of a narrow zone (usually 2-3 layers) of sclerenchyma lying below the epidermis.

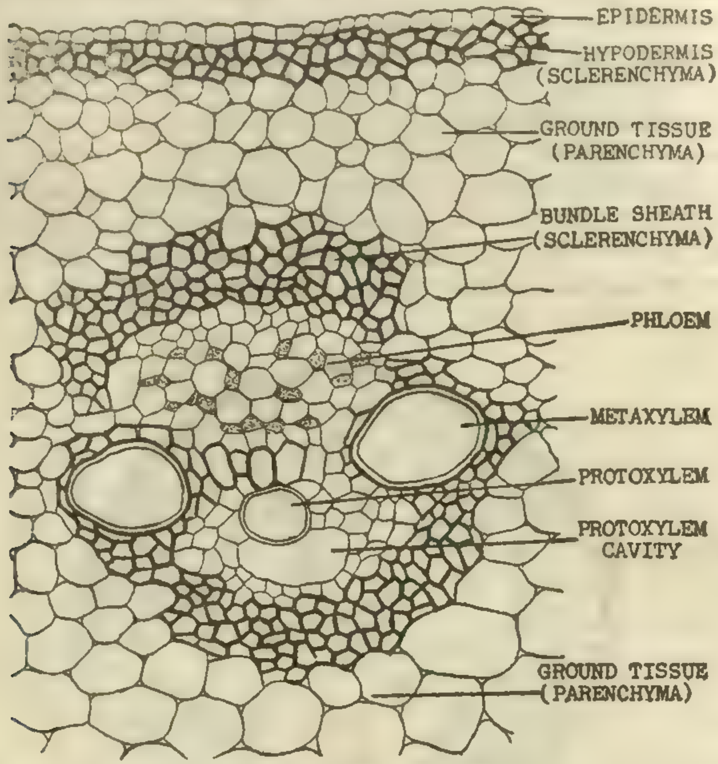


Fig. 136. Portion of a transverse section of a Maize stem showing only one vascular bundle. In the phloem region the companion cells are shaded.

3. **Ground tissue**—It consists of an undifferentiated mass of thin-walled parenchyma with small intercellular spaces. It is in the ground tissue that the vascular bundles are embedded. On account of the scattered arrangement of the vascular bundles the ground tissue is not differentiated into cortex, starch sheath, pith and medullary rays.

4. **Vascular bundles**—The most characteristic feature of the stem of Maize is the large number of vascular bundles scattered irregularly through it. Towards the periphery the bundles are smaller and are crowded together; they are large and more isolated

in the central region. The bundles are closed collateral, there being no cambium between the xylem and the phloem. They are more or less oval in outline and each one is surrounded by a sheath of sclerenchyma. The xylem is directed towards the centre of the stem and the phloem towards the periphery.

The *xylem* is composed of 2 or 3 annular or spiral vessels forming the *protoxylem*, and two large pitted vessels which form the *metaxylem*. One or two of the protoxylem vessels usually disorganise very early and by their disorganisation a cavity is formed (*protoxylem cavity*). The two large pitted vessels and the small protoxylem vessels are arranged in the form of a *V or Y*. The protoxylem is surrounded by some parenchyma cells (*xylem parenchyma*). On the outer face of the protoxylem are found a few *tracheids*.

The *phloem* consists entirely of sieve tubes and associated companion cells and lies partly between the two larger vessels. Phloem parenchyma cells are absent.

Dicotyledonous and Monocotyledonous Stems—a comparison.

Dicotyledon	*Monocotyledon*
(i) The ground tissue is differentiated into cortex (including collenchyma (hypodermis), parenchyma and starch sheath), pith and medullary rays.	(i) The ground tissue is not so differentiated. Below the epidermis is found a few layers of sclerenchyma forming the hypodermis. The rest of the ground tissue forms an undifferentiated mass of parenchyma through which the vascular bundles pass.
(ii) The vascular bundles are few in number and are usually arranged in a ring; they are collateral or bicollateral, and have always a strip of cambium between the xylem and the phloem (open).	(ii) The vascular bundles are many in number and are scattered throughout the stem; they are collateral, but have no cambium between the xylem and the phloem (closed).
(iii) The bundles are not surrounded by a sheath of sclerenchyma, but usually have a patch of sclerenchyma just above the phloem forming what is known as the hard-bast or bundle cap.	(iii) Each one of the bundles is surrounded by a sheath of sclerenchyma.
(iv) The xylem of a bundle is composed of many vessels which are arranged in more or less radial rows. The smaller vessels forming the protoxylem are towards the centre of the stem, while the bigger vessels forming the metaxylem are towards the circumference.	(iv) The xylem of a bundle is composed of a few vessels. There are only 2 or 3 annular and spiral vessels (protoxylem). The metaxylem is composed of only 2 large pitted vessels. The arrangement is the same as in dicotyledons, i.e., the protoxylem lies towards the centre of the stem and the metaxylem towards the circumference.

Dicotyledon

(v) The phloem is composed of sieve tubes, companion cells and phloem parenchyma.

(vi) Cambium is always present between the xylem and the phloem, and is responsible for the secondary growth in thickness of dicotyledonous stems.

Monocotyledon

(v) The phloem is composed of sieve tubes and companion cells. Phloem parenchyma is absent.

(vi) Cambium is absent, so secondary growth in thickness is not possible in monocotyledonous stems.

STRUCTURE OF ROOTS

Structure of a Young Gram (Dicotyledon) Root [Fig. 137]

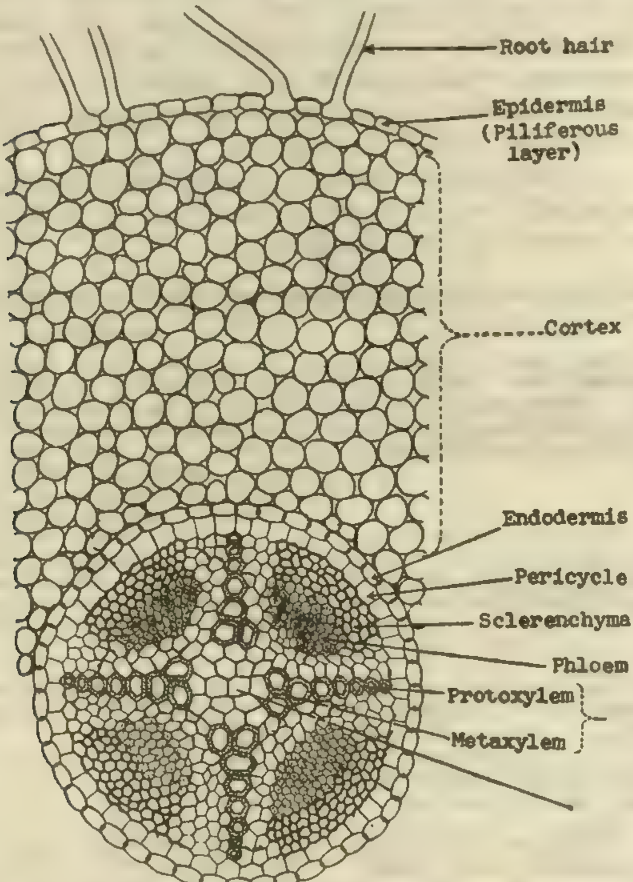


Fig. 137. Portion of a transverse section of a young root of Gram showing the arrangement of the different tissues.

The young root is typically cylindrical and so in a transverse section it will appear circular. In a thin section the following tissues are observed from the periphery towards the centre.

1. **Epidermis or piliferous layer**—It consists of a single layer of thin-walled cells without any cuticle upon their outer walls. The epidermis of roots is also called the piliferous layer (*pilus*—hair, *ferous*—bearing), because many of its cells extend outwards forming hairs (roots hairs).

2. **Cortex**—The cortex forms an extensive tissue and lies below the epidermis. It consists of thin-walled and nearly rounded cells which may contain starch grains. The cells are separated at the corners by intercellular spaces.

The *endodermis* is the innermost layer of the cortex and is composed of a single layer of barrel-shaped cells without any intercellular spaces between them. The cells are, therefore, different in appearance from the other cortical cells. The radial walls of the cells of the endodermis have peculiar thickenings.

[The stele is the central portion of the root and is found within the endodermis. It is bounded externally by the pericycle, a single layer of thin-walled cells. The strands of xylem and phloem pass through the stele.]

3. **Pericycle**—It consists of a single layer of thin-walled cells lying just within the endodermis. By the division of the cells of the pericycle lateral roots take their origin.

4. **Vascular bundles**—They are radial; there are four strands or bundles of xylem and four of phloem alternating with one another. In each xylem strand the smaller vessels abutting on the pericycle constitute the protoxylem; they are either annular or spiral. The vessels gradually become larger towards the centre. These larger vessels which are either reticulate or scalariform, constitute the metaxylem. Each phloem strand consists of sieve tubes, companion cells and phloem parenchyma. On the outer side of each phloem strand lies a patch of sclerenchyma cells.

The cambium which is responsible for the secondary growth in thickness is absent in a very young root. It, however, develops later on.

5. **Conjunctive tissue**—It consists of parenchyma cells intervening between the xylem and the phloem bundles.

6. **Pith**—It consists of thin-walled parenchyma cells occupying only a small area in the centre of the root.

Structure of a Monocotyledonous Root [Fig. 138]

The structure of a monocotyledonous root as revealed in a thin transverse section is shown in Fig. 138. The general arrangement of the different tissues is essentially the same as found in a

young dicotyledonous root. The following points of difference should be noted.

(i) There is a large number of xylem and phloem strands (bundles). The metaxylem vessels are comparatively wider.

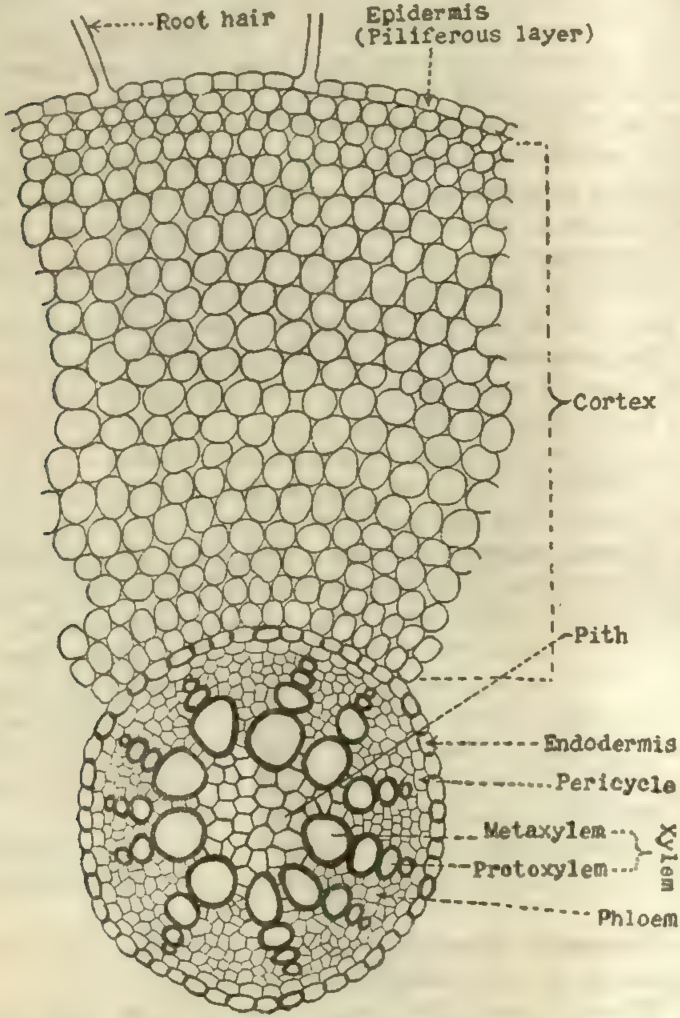


Fig. 138. Portion of a transverse section of a root of *Alocasia* (B. Mankachu) showing the distribution of the different tissues.

(ii) The pith is large and persistent, while in dicotyledons it is soon replaced by the developing xylem.

(iii) The structure of the pericycle is essentially the same in

both dicotyledons and monocotyledons. In dicotyledons it develops secondary roots and cambium (partly) but in monocotyledons it develops only secondary roots.

STRUCTURE OF LEAVES

Structure of a Dorsiventral Leaf [Fig. 139]

In a dorsiventral leaf the adaxial (upper) surface facing upwards is more strongly illuminated than the abaxial (lower). On account of this unequal illumination of the two surfaces the ground tissue of such a leaf has been unequally differentiated on the two surfaces. In a thin transverse section of the leaf passing through the midrib the following arrangement of the tissues will be observed:

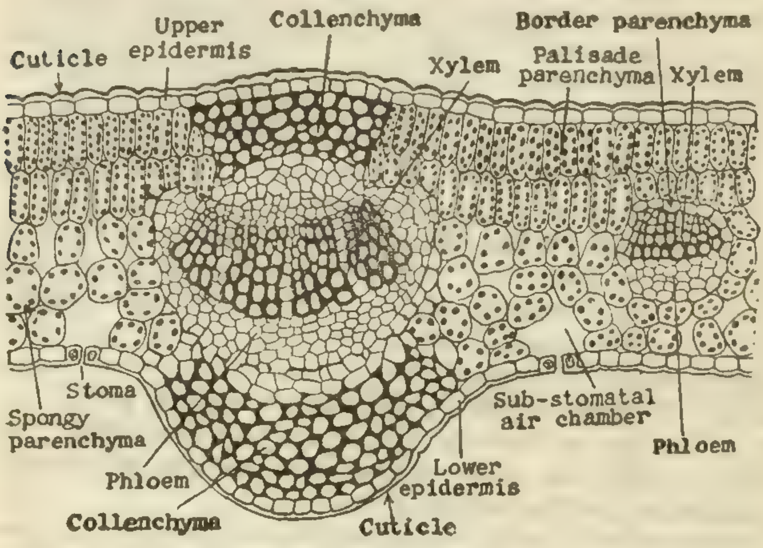


Fig. 139. Transverse section of part of a dorsiventral leaf passing through the midrib and one small lateral vein.

1. Epidermis—(i) Upper epidermis—It consists of a single continuous layer of cells. The outer walls of these cells are thickened and cuticularised and form a special colourless layer known as the cuticle. There are usually no stomata in the upper epidermis. The cells of the epidermis do not contain chloroplasts.

(ii) Lower epidermis—It also consists of a single layer of cells. The continuity of the cells of the lower epidermis is broken here and there by a number of opening called stomata through

which communication takes place between the external air and the intercellular spaces within.

2. Mesophyll—The ground tissue of the leaf lying between the two epidermal layers is known as the mesophyll. It consists of two kinds of parenchyma cells, *palisade parenchyma* and *spongy parenchyma*.

(i) Palisade parenchyma—These cells lie next to the upper epidermis, and are thin-walled and oblong in form. They stand parallel to one another with their long axes at right angles to the surface of the leaf. They are arranged in one or more compact layers (two are shown in figure 113) with small intercellular spaces between them, and contain a large number of chloroplasts.

(ii) Spongy parenchyma—The mesophyll cells towards the lower surface are less regular in form and arrangement. They are in several layers and are more or less roundish in form. Chloroplasts in these cells are not so numerous as in the palisade cells. The intercellular spaces between these cells are very large and numerous and on account of this the tissue is described as the *spongy parenchyma*. Opposite each stoma is found a specially large air-cavity which is called the *substomatal air chamber*.

3. Vascular bundles—The vascular bundles or the veins are numerous in a leaf. They pass from the base of the leaf and gradually become smaller and smaller. The larger bundles (midribs) extend from the upper to the lower epidermis, but the smaller bundles (lateral veins) lie between the palisade and spongy parenchyma. The larger bundles of the midribs are usually strengthened by collenchyma tissue present on their upper and lower sides. The smaller bundles are usually surrounded by a sheath of colourless parenchyma called the *border parenchyma*.

Each bundle consists of xylem lying towards the upper surface and phloem towards lower surface. The xylem is composed of annular and spiral vessels, a few tracheids, wood fibres and wood parenchyma. The phloem is composed of sieve tubes, companion cells and parenchyma cells. Through the xylem water and raw food materials are conducted and distributed to the different parts of the leaf. The sieve tubes transport the prepared food from the leaf.

Structure of Isobilateral Leaves [Fig. 140]

In many plants, especially among the monocotyledons, the leaves hang perpendicularly downwards or are held erect, and are, therefore, equally illuminated on both surfaces. On account of this

the mesophyll of such leaves is not differentiated into palisade and spongy parenchyma. Such leaves are usually called isobilateral

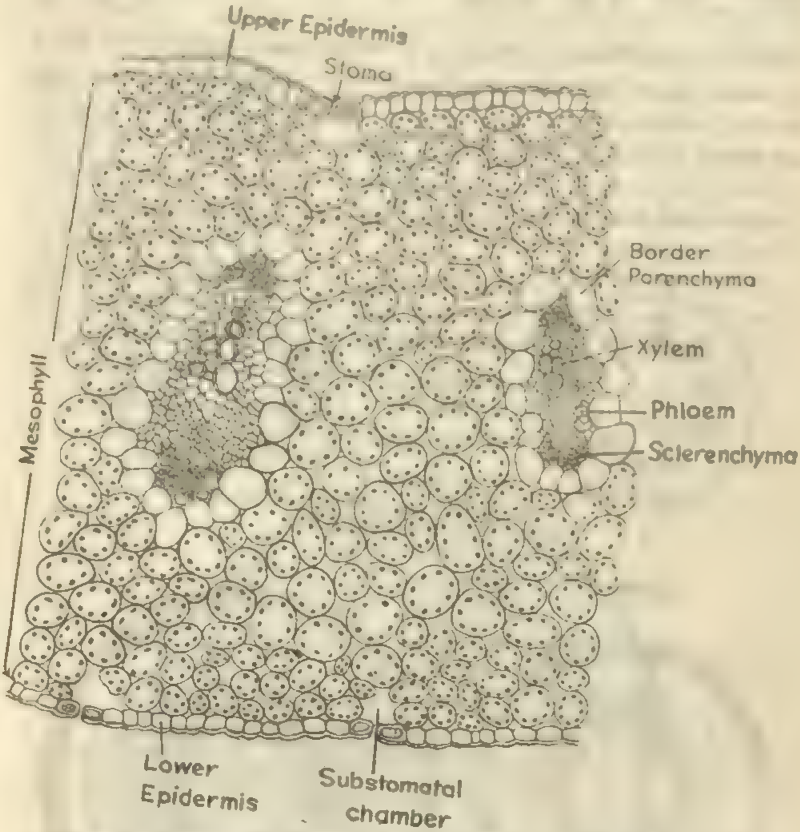


Fig. 140. Transverse section of an isobilateral leaf of *Polyanthes* (B. Rajanigandha). Note that the mesophyll is not distinguished into palisade and spongy parenchyma and the stomata are present on both surfaces of the leaf.

leaves. In isobilateral leaves sclerenchyma is developed, particularly on the upper and lower sides of the vascular bundles.

SECONDARY GROWTH IN THICKNESS

Increase in thickness of the stems and roots of dicotyledons is at first due to the enlargement of the cells of the primary tissues, viz., the epidermis, cortex, phloem, xylem, medullary rays and pith. Such increase is known as primary growth in thickness and takes place so long as the stem or the root is elongating. This

type of growth in thickness, however, ceases very early and further growth in thickness is due to the development of additional tissues by the activity of the cambium.

Secondary Growth in Thickness in Dicotyledonous Stems [Fig. 141]

Soon after the differentiation of the primary tissues the cells of the *fascicular cambium*, that is, the cambium lying between the xylem and the phloem, divide rapidly and produce new tissues to the xylem towards the inside and to the phloem towards outside. At this time the cells of the medullary rays lying between the two

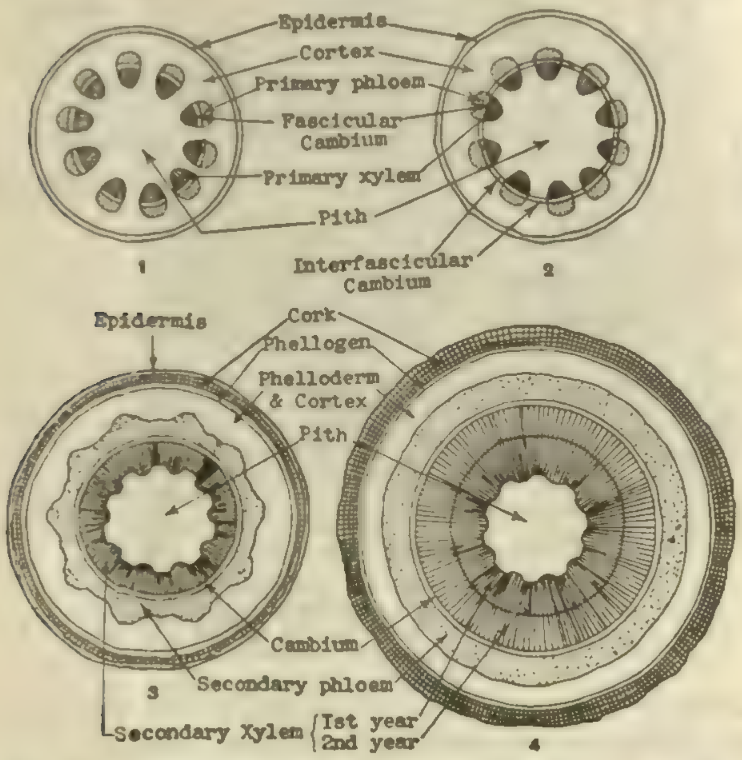


Fig. 141. Diagrams of transverse sections of dicotyledonous stems showing stages in secondary thickening. In the last stage (Fig. 4) two annual rings can be seen.

fascicular cambium layers become meristematic and form the *interfascicular cambium*. This joins with the fascicular cambium on both sides ; thus a complete cambial ring is formed [Fig. 141, 2]. The cells of this cambial ring continually produce *secondary tissues*.

As there is no limit to the repeated divisions of the cambial cells, a great increase of the tissues is the result. The cambium is more active towards the inner side and so a greater amount of secondary xylem is produced. As a result of greater production of secondary xylem, the cambium and phloem elements are pushed towards the periphery; and due to the pressure of the tissues from within, the primary phloem is crushed and finally becomes altogether functionless.

Some cells of the cambium ring which are almost isodiametric, are called the *ray initials.* These cells instead of producing xylem and phloem, develop parenchyma cells in the radial direction. These cells form the secondary medullary rays. They serve as means of ventilation and of conduction of material in the radial direction through the xylem and phloem.

Annual rings [Figs. 141, 4 & 142]–In many plants the cambium is not uniformly active throughout the year. A period of

Fig. 142. Transverse section of an old dicotyledonous stem showing annual rings. The heavily stippled region represents the bark consisting of secondary phloem, cortex, phelloderm and cork.

great activity alternates with a period of rest or less activity and as a result there is a marked difference between the wood formed at the beginning and at the end of the period of activity. In spring, the period of active vegetation, the roots absorb a large quantity of water; the cambium at this season produces a large number of

wide vessels, which form the *spring* or *early wood*. In autumn and winter the cambium is less active and develops usually a comparatively small number of narrow vessels, and narrow fibres and tracheids with thick walls which together form the *autumn* or *late wood*. In this way two distinct layers of secondary wood or xylem are produced each year; these two layers together from one *annual ring*. When the small thick-walled elements of the late wood are succeeded by another increment of thin-walled elements of the early wood, the contrast between the two becomes quite obvious. Thus, between the two succeeding rings a sharp line of demarcation is visible even to the naked eye. The annual rings are produced year after year and appear as concentric rings in the transverse section of a stem. By counting the number of annual rings the age of the plant can be accurately determined.

Heart-wood and Sap-wood—In old trees the inner portion of the stem or root is markedly differentiated from the outer portion. The central portion ceases to function as the water-conducting tissue and serves only for support. It becomes harder and firmer than the outer parts and usually becomes dark-coloured by the deposition in the cell-wall and in the cell cavities of substances like tannin, gums, resins, etc. This region is called the *heart-wood*. The zone of wood outside the heart-wood which performs the function of conduction is called the *sap-wood*.

Extra-stelar Secondary Growth

The cambium ring continually produces secondary xylem and secondary phloem. The new tissues exert considerable pressure on the cortical tissues which are greatly stretched. The thin-walled cortical parenchyma cells commonly increase in number by radial division to keep from breaking apart. Further increase in thickness of the cortex takes place by the formation and continued activity of a secondary meristem called *phellogen* or *cork-cambium* [Fig. 164] which takes its origin usually in the outer cortical region. The phellogen produces *phelloderm* or *secondary cortex* consisting of thin-walled parenchyma or collenchyma on its inner side and *cork* on its outer side. *Cork* consists of brick-shaped cells which soon lose their contents; their walls become suberised. The cells are compactly arranged having no intercellular spaces between them. Thus the cells of the cork form a complete protective covering of the internal tissues. Cork is impervious to air and water and so the spidermis is cut off from the living tissues within and dries up.

Lenticel [Fig. 143]—With the formation of cork which is impervious to air and water interchange of gases between the inner tissues and the outer air becomes impossible. Communication is established here and there by the formation of special pores called *lenticels.* At some places the phellogen, instead of developing

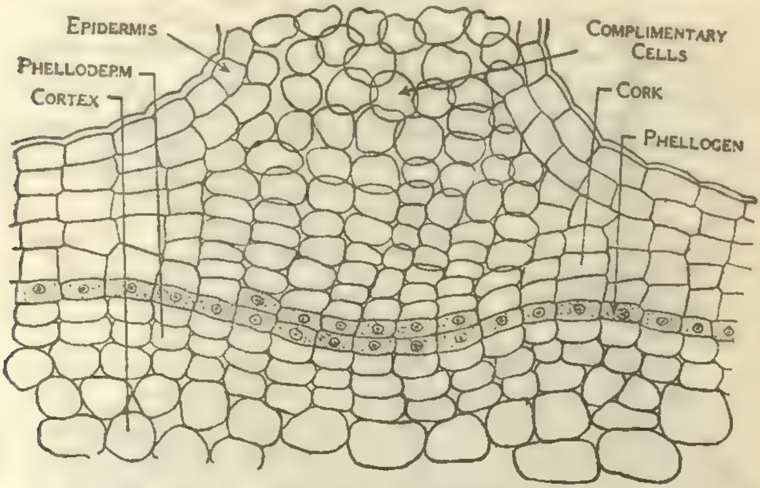


Fig. 143. Transverse section of a dicotyledonous stem showing phellogen, cork and secondary cortex and also a lenticel.

corky, cells, gives rise to large thin-walled loosely organised cells having many intercellular spaces between them. They are commonly known as *complementary cells.* They become exposed to the air by the rupture of the epidermis above them. The entire structure which interrupts the continuity of the cork cells is the *lenticel.* Lenticels always develop just beneath the stomata. To the naked eye they appear as so many brown or white streaks on the surface of mature stems.

Bark—The term "bark" should not be used in a technical sense. In non-technical sense the term "bark" is applied to all the tissues lying outside the cambium of the vascular cylinder. The term in non-technical usage, that is, in a general sense, comprises the following tissues, viz., the cork, cork-cambium, phelloderm, cortex and phloem.

Secondary Growth in Thickness in Dicotyledonous Roots [Figs. 144 & 145].

Dicotyledonous roots can grow in thickness in the same manner as do dicotyledonous stems. In roots xylem and phloem

by themselves form separate strands or bundles which do not have any cambium. At the beginning of secondary growth the cells of the conjunctive parenchyma lying on the inner side of the phloem become meristematic and form a strip of cambium. Cambium also

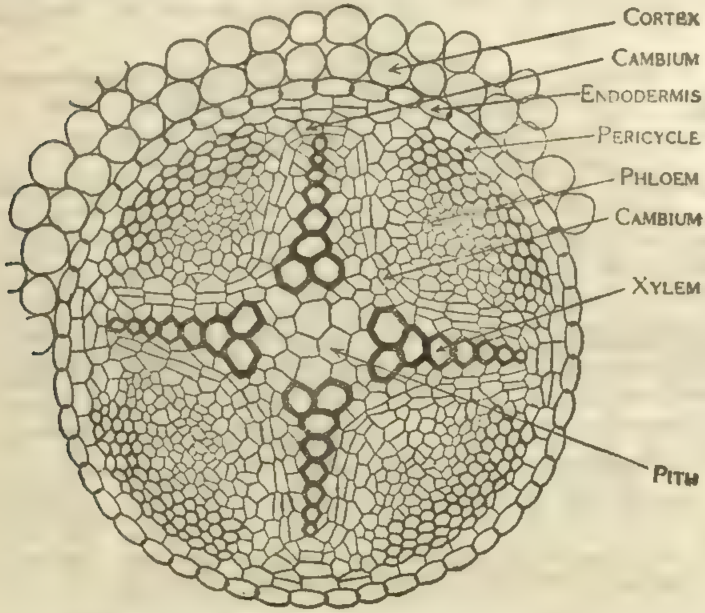


Fig. 144. Transverse section of a dicotyledonous (Gram) root showing the formation of cambium at the beginning of secondary growth.

arises similarly in the pericycle just opposite the xylem strands. The cells of the conjunctive tissue lying between the xylem and phloem strands also become meristematic and join with the two other strips. Thus a continuous ring of cambium is developed which is at first sinuous. This cambium ring develops xylem on its inner side and phloem on its outer side. As growth proceeds the sinuous cambium ring becomes circular on account of the production of a large amount of secondary tissues on its inner side.

Further development is similar to that of the stem.

Growth in Thickness of Monocotyledonous Stems

In monocotyledonous stems the vascular bundles do not have any cambium and consequently there is no secondary growth in them. But the stem of an old monocotyledonous stem, like that of Maize or Sugar cane, is much thicker than the stem which the plant had when very young. There are many monocotyledons,

like the Palms, the stems of which are considerably thickened. The increase in thickness of stems of monocotyledons is not due to the formation of tissues, but it takes place in an entirely different way. As growth proceeds, the growing point of the very young

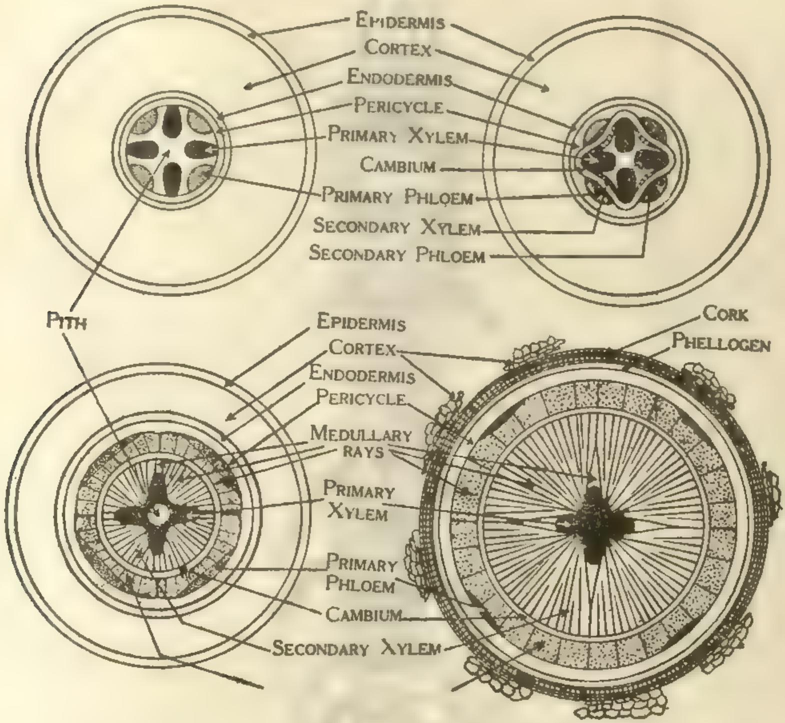


Fig. 145. Stages in the secondary growth of dicotyledon roots (diagrammatic).

plant becomes continually larger and more vigorous, so that each successive node and internode become larger than those formed below. The young stem has thus the form of an inverted cone. This method of enlargement continues until the apex attains the full thickness natural to the particular plant; so the internodes formed subsequently are of equal width and therefore the upper portion of the stem becomes cylindrical. The lower portion of the stem which has the shape of an inverted cone usually remains buried underneath the soil. Stems of monocotyledons thickened in this way usually have rigidity chiefly because of the large development of sclerenchyma sheaths [Fig. 146].

Secondary Growth in Monocotyledonous Stems

Secondary increase in thickness takes place only in a few monocotyledonous stems like *Yucca, Dracaena,* bulbs of *Polyanthes* (B. Rajanigandha) and a few others. A secondary

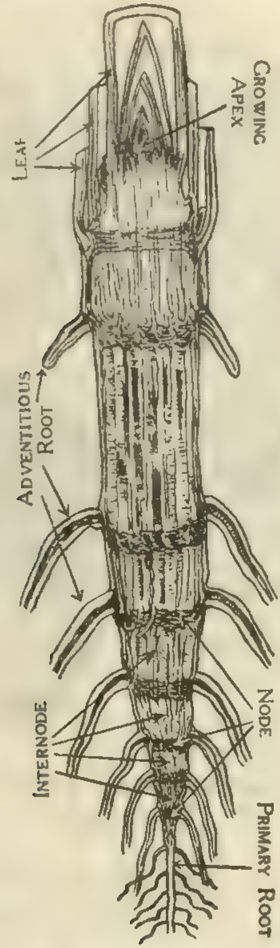


Fig. 146. Longitudinal section of a maize stem showing the pattern of growth in thickness.

cambium layer develops in the cortex and forms a complete ring. This cambium, instead of producing xylem on its inner side and phloem on the outer side, develops sclerenchyma and complete vascular bundles composed of xylem and phloem on the inner side. A phellogen is formed later in the hypodermal region which produces cork on its outer side and secondary cortex on the inner side.

ZOOLOGY

1

OUTLINE CLASSIFICATION OF ANIMAL KINGDOM

Several millions of animals inhabit the earth; they are present in almost every region of the earth and are of diverse types. Some are small others are large; some are simple and others have complex structures. Of these millions of animals, some occur in land and others in water or air. For proper identification, nomenclature, etc. of such a vast number of animals it is necessary to arrange or classify them into groups. Such arrangement is known as classification. The classification of animals is mainly based on important similarities and dissimilarities of their external as well as internal structures.

The animal kingdom is subdivided into two major groups: (i) **Achordata** or **Nonchordata** and (ii) **Chordata** on the basis of the absence or presence of notochord. In Achordata both notochord and vertebral column are absent. Achordata are sometimes referred to as invertebrates. In chordates notochord is present. In some chordates the notochord is later on replaced by the vertebral column. Thus animals which have a backbone supporting the body are vertebrates (e.g. fish, dogs, man, etc.) and animals lacking a backbone are invertebrates (e.g. *Amoeba*, butterflies, etc.).

From another point of view the animal kingdom is divided into two subkingdoms, namely, **Protozoa** and **Metazoa**, on the basis of the number of cells that make up their body. The body of protozoan is made up of only one cell (unicellular), (e.g., *Amoeba*); whereas the body of metazoan is made up of many cells (multicellular), e.g., *Hydra*, earthworm, bee, bird, horse, etc.

The **Protozoa** has only one phylum, whereas the **Metazoa** has several phyla (Table 1). A *phylum* is a group which includes all animals that resemble one another in their general structure. These similarities suggest that they probably have originated from a common ancestor. Phylum (Pl. *Phyla*, Greek: *Phylon*-generation) is a major unit in zoological classification. There are about ten major phyla which include the common animals. Besides

these, there are about thirteen to fourteen major phyla, which include fewer and comparatively less known species. The number of minor phyla in different systems of classification varies.

TABLE : 1.

Animal Kingdom

Subkingdom Protozoa (unicellular)	Metazoa (Multicellular)
Phylum Protozoa	Phylum 1. Porifera
	2. Coelenterata
	3. Platyhelminthes
	4. Nemathelminthes
	5. Annelida
	6. Arthropoda
	7. Mollusca
	8. Echinodermata
	9. Chordata (Vertebrata)

The **Achordata** is subdivided into nine phyla. The animals belonging to **Chordata** are grouped together under one phylum (Table 2).

ACHORDATA

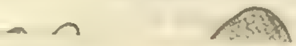
Phylum 1 **Protozoa** (Greek : *Protos*-first, *zoon*-animal)

The most primitive animals belong to this group. They are simple, unicellular, microscopic organisms. The single cell performs all the vital activities, such as, respiration, nutrition, movement, reproduction, etc. The shape of the cell is variable; it may be spherical ovate, elongated or irregular. Locomotion is exhibited either by *pseudopodia* (sing. *pseudopodium*-false foot) or by *flagella* (sing. *flagellum*), which is a long filamentous projection at one end of the body, or by *cilia* (sing. *cilium*). Cilia are fine hair like structures, occurring all over the body and locomotion is exhibited by their co-ordinated beating.

Protozoa (Fig. 1) can live autophytically, parasitically, or symbiotically. Asexual reproduction takes place by cell division, binary fission, multiple fission or by budding. Sexual reproduction take place by conjugation.

Protozoans occur in fresh water, saline water, dampy soils and also as parasites, e.g., *Entamoeba* occurring as parasite on man causes dysentry. *Trypanosoma* is another parasite which causes

sleeping sickness. Certain protozoans live in groups forming colonies.



The phylum protozoa is divided into four classes
their locomo-
res and types
ion.

Sarcodina—
by psedopo-
oeba.

. **Flagellata**—
by fiagella,
a.

3. **Ciliata**—
by cilia, e.g.
um.

4. **Sporozoa**—
eproduction by
, e.g. *Mono-*

Porifera (Latin :
ore, *ferre*-to

a includes the
tive multicellu-
, usually known
(Figs. 2 & 3)
earing animals.
no organized
organs and the
sponges remain
usually marine,

urrounded by a
). Many small

pores, known as *ostia* occur all over the body wall. Water flows through these pores into the body cavity which opens at the apex by a larger pore. Sponges depend for their food and oxygen on this incurrent water. There are records of nerve cells occurring in sponges.

The skeletal elements are characteristic of sponges. The body

is provided with spiny structures, which are known as *spicules.* The spicules may be calcareous (made up of calcium carbonate) or siliceous. In certain cases the spicules have some cementing fibres of a horny substance called *spongin.*

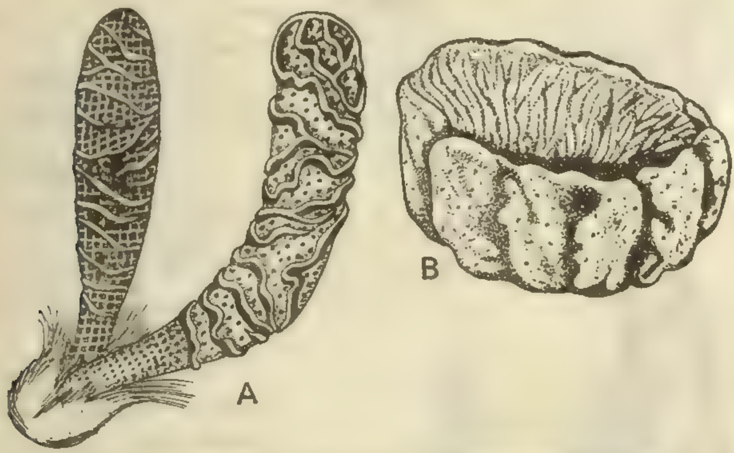


Fig. 2. A—Glass rope sponge, B—Commercial sponge.

Porifera are divided into 3 groups according to their skeletal elements: 1. **Calcarea** have calcareous spicules, e.g., *Sycon.*

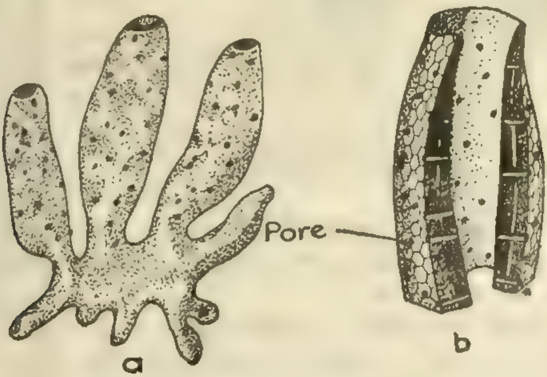


Fig. 3. Simple sponge, a—whole, b—longitudinal section.

2. **Hexactinellida** or glass sponges have siliceous 6- rayed spicules. e.g., venus flower busket, *Hyalonema*, etc. 3. **Demospongia** have siliceous spicules of different type than the above or have songin or no skeleton ; e.g., Commercial (bath) sponge (Fig. 2B), *Cliona.*

Phylum 3 **Coelenterata** (Greek: *Kolios*—hollow, *enteron*—intestine)

Usually radially symmetrical. Body is hollow and made up of two cellular layers so they are called diploblastic animals. In between these two layers a jelly-like layer known as *mesoglea*, is present. Nerve cells are embedded in the mesoglea. The body has a single gastral cavity known as colenteron which is connected with the exterior by a pore, called the mouth. This pore also serves as an anus. Around the mouth there are a number of *tentacles*. Many tentacles are provided with stinging cells, called *nematocysts*. These stinging cells are used for defence and also capture of the prey.

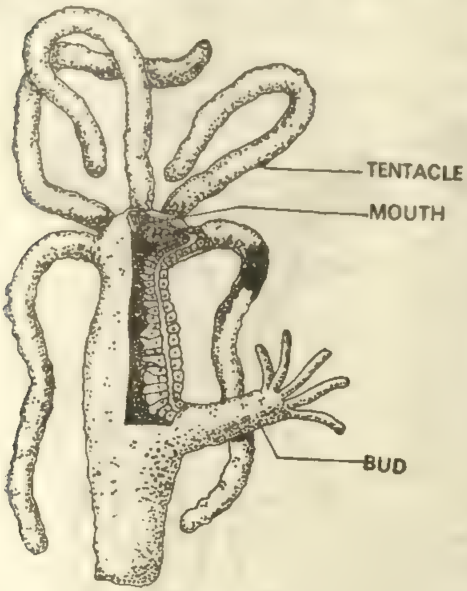


Fig. 4. *Hydra with bud.*

Two type of Colenterates (Figs. 4-6) are found, namely, (a) with tube like polyp which remains attached to the ground and (b) with floating umbrella shaped medusa.

Some Coelenterates are solitary, others colonial. They are usually marine, but some live in fresh water.

Coelenterata is divided into two subphyla :

Subphylum 1. **Ctenophora**—Comb jellies, nematocyst absent, e.g., Sea gooseberry (*Pleurobranchia*).

Subphylum 2. **Cnidaria**—nematocyst present. Subdivided into 3 classes : (a) Hydrozoa—Sedentary, colonial, hydroid forms, e.g., *Hydra* (Fig. 4), *Obelia*, *Physalia* (Fig. 5). (b) Scyphozoa—Jelly fishes with dominant medusoid stages, e.g., *Aurelia*. (b) Actinozoa—No medusoid stage, body complex, e.g., Sea anemone (Fig. 6).

Phylum 4. **Platyhelminthes** (Greek: *Platy*-flat, *helminthes*-worm).

More advanced than Coelentarata and possesses a bilaterally symmetrical, dorsoventrally flattened, triploblastic body (body

made up of three true layers of cells). Excretory system, nervous system and complex reproductive system are present. There are special cells, called flame cells for the elemination of excretory substances. The alimentary canal is incomplete with only one opening, the anus being absent. Blood vascular system and body cavity or coelom is absent. The mouth is situated on the ventral

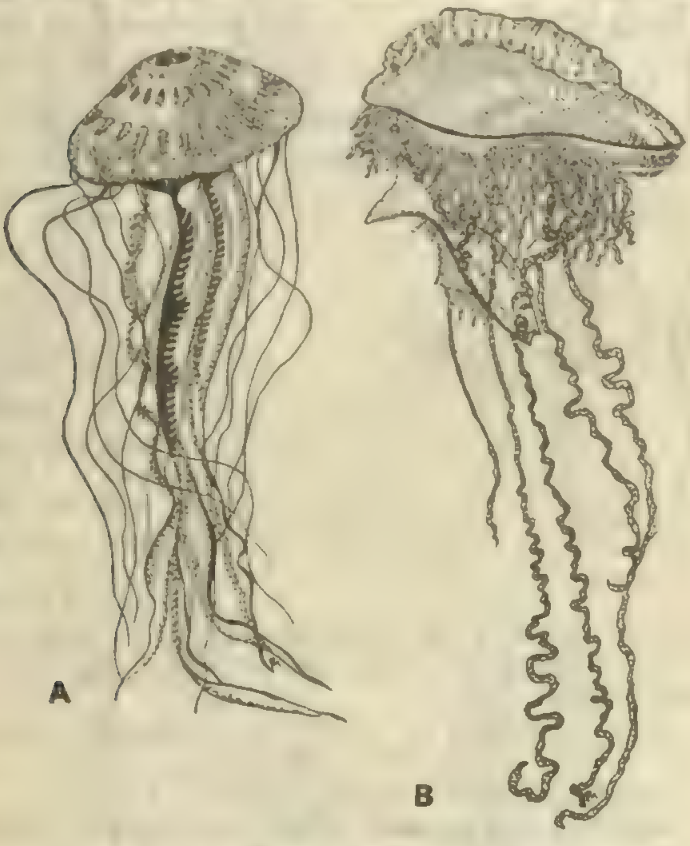


Fig. 5. Jelly fishes; A—Sea nettle (*Dactylometra*)
B—Portuguese Man-O-War (*Physalia*).

surface near the anterior end. The mouth leads to a gut. In extreme parasitic forms gut and mouth are absent.

Free living or parasitic (mostly endoparasites) occur in water or on soil in dampy places; usually bisexual.

There are three classes of Platyleminthes: 1. **Turbellaria**—Usually free living, e.g., *Planaria* (Fig. 7A), *Polycelis*, etc.

2. **Trematoda**—Parasitic and have gut, e.g., *Fasciola*, Liver fluke (Fig. 7B). 3. **Cestoda**—Endoparasitse, have no gut, e.g., *Taenia* (tape worm) (Fig. 37).

Phylum 5. **Nemathelminthes** or **Nematoda** (Greek: *Nematos*-thread, *helminthes*—worm).

Fig. 6. Sea anemonies.

They are sometimes referred to as round worms (Fig. 7C). They appear round in transverse section and have a cylindrical, elongated body, which tapers towards both ends. Body bilaterally symmetrical and covered by cuticle. The respiratory and circulatory systems are absent. The body has a false body cavity (pseudo-coelomare). The digestive system is provided with a mouth and anus. They are small, unisexual animals.

Free living or parasitic. Parasitic forms causes various diseases of plants and animals e.g., filarial worm (*Wuchereria*) causes filaria, *Ascaris*, Hook worm (*Ancylostoma*), Round worm (*Rhabditis*), etc.

Phylum 6. **Annalida** (Latin: *Annulus*-ring).

Usually known as segmented worms. Body is elongated, bilaterally symmetrical and consists of several ring like segments or annulus. They have true coelom (body cavity). The body is often provided with many slender structures known as *setae* (sing. seta), with the help of which the animal can move. In some cases, sucker (e.g., leech) is present. The animals possess complete digestive system, closed circulatory system, muscular system, nervous system and excretory system. The muscular system is made up of outer circular and inner longitudinal muscular fibres in the body wall. A dorsal brain and a ventral nerve cord with a pair of ganglia (in each segment) and lateral nerves form the nervous system. A pair of *nephridia* (sing. nephridium) in each segment forms the excretory system. They occur in fresh water, in saline water or in dampy soil and are unisexual or bisexual.

Annelida is divided into three main classes, namely:

1. **Polychaeta** (Fig. 8)—marine bristle and paddle worms,

e.g., *Chaetopterus*, *Cirratulus*, *Tomopteris*. 2. **Oligochaeta**—fresh water froms, sucker absent, e.g., *Tubiflex*, earthworm (*Lumbricus*), etc. Earthworms (Fig. 9) are called natural tiller of the soil, because they make underground burrows thereby

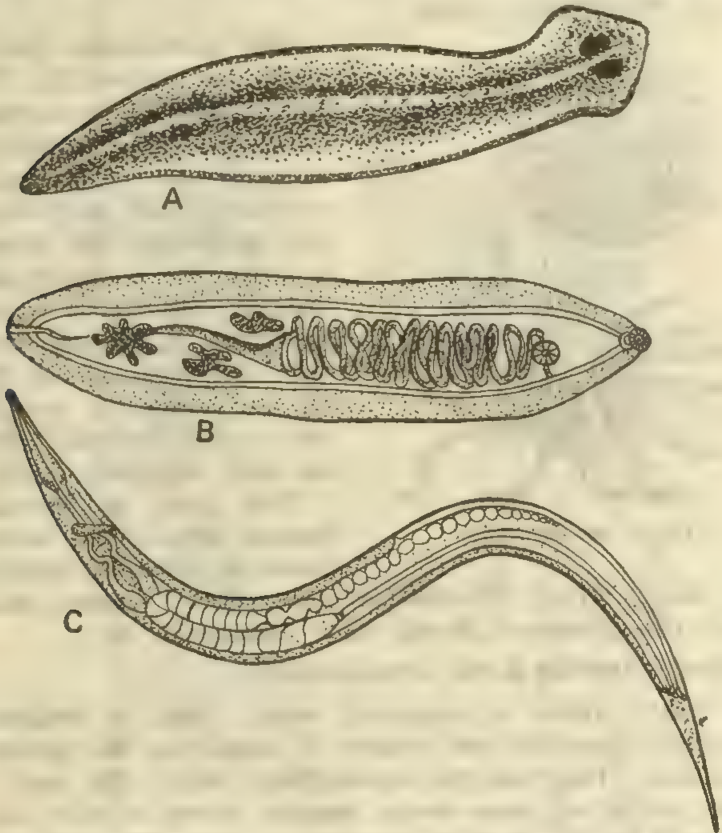


Fig. 7. A—*Planaria*, B—Liverfluke, C—Round worm (*Rhabditis*).

loosening the soil. 3. **Hirudinae**—have 33 segments, no bristles, anterior and posterior sucker present, bisexual but cross fertile, e.g., Leeches (*Hirudo*) (Fig. 10) are ectoparasites and suck the blood of other animals. Besides these, three other groups, Archiannelida, Echiuroidea and Siphunculoidea are given class status by some scientists.

Phylum 7 **Arthropoda** (Greek : *Arthros*-jointed, *podos*—legs).

Arthropods form about 80% of all recorded living species of animals. They include the only invertebrates, which can fly. Bilate-

rally symmetrical, joint-footed animal with a segmented body which is covered by a hard chitinous exoskeleton. The exoskeleton is shed periodically as it hampers growth. The process of shedding of exoskeleton is known as moulting. Nervous system is like annelids. Digestive system is complete. Respiration takes place

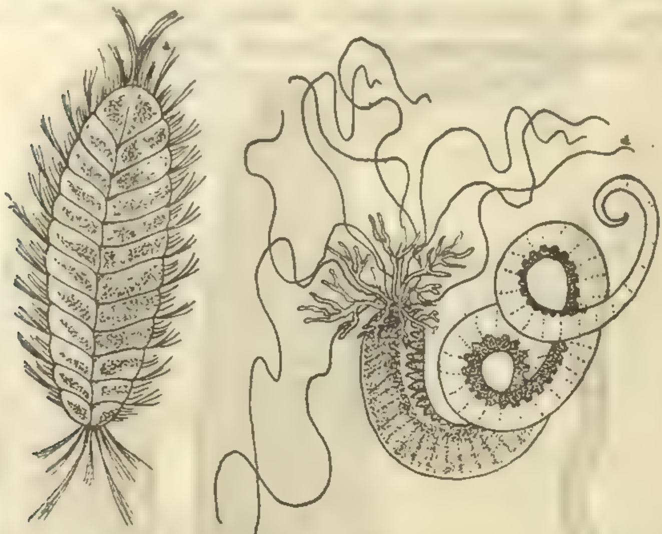


Fig. 8. Polychaete.

by tracheae, gills, book lungs or body-surface. The circulatory system is of open type and the malpighian tubules or green glands are the excretory organs. The body cavity is blood filled and is known as haemocoel. The body is made up of head, thorax and abdomen. In some, the head and thorax are united forming the cephalothorax. The eye is compound.

Unisexual, aquatic or terrestrial animals and have cosmopolitan distribution.

The main living classes are: 1. **Onychophora**—Most ancient group, have no water proof cuticle, e.g., *Peripatus* (Fig. 11A). 2. **Crustacea**—Two pairs of antennae are present as the most anterior head appendages, e.g., *Balanus* (Fig. 11C), *Daphnia* (Fig. 12), Lobster. 3. **Myriapoda**—Elongated body with many legs bearing segments, e.g., centipeds (Fig. 11B), 4. **Insecta**—Body divided into head, 3 pairs of legs, thorax and abdomen, e.g., Ant, Bee, Butterfly (Fig. 13), Moth, Silk-moth, House-fly (Fig. 13), 5. **Arachnida**—Head and thorax united, e.g., King crab (*Limulus*), Spider, Scorpion (Fig. 14), etc.

Phylum 8 **Mollusca** (Latin: *Mollis*-soft).

Second largest invertebrate phylum, widespread, aquatic (marine and freshwater) and terrestrial. Body bilaterally symmetrical, unsegmented, soft, covered by a fleshy mantle which usually secretes a shell of calcium carbonate. There are however, a few exceptions. In *Octopus* the shell is absent. In Sepia and Loligo shell is present inside the body. Usually unisexual.

Fig. 9. Earthworm.

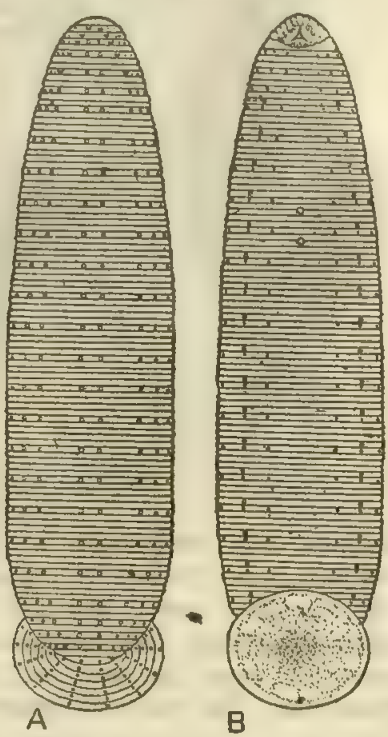


Fig. 10. Leech A—Dorsal view, B—Ventral view.

The body usually consists of four parts, namely, (a) head bearing tentacles, eyes, mouth, brain, etc., (b) visceral sac bearing gut, heart, reproductive organs etc., (c) muscular foot, used for locomotion and burrowing and (d) the mantle, which is a fold of the skin that separates the shell from rest of the body. On account of the nature of the shells the molluscs are easily fossilized and numerous fossil molluscs have been found.

There are several classes, namely:

1. **Amphineura**—Body elongated, shell of eight plates or none, no tentacles, e.g., Chiton, Neomenia.

2. **Scaphopoda**—Body tubular with elongated curved shell, open at both ends, e.g., Dentalum.

3. **Gastropoda**—Largest group, shell present but does not have two valves, e.g., *Pila* (snail) (Fig. 15A), *Achatina*, *Cypraea* (Cowries), *Limnaea*.

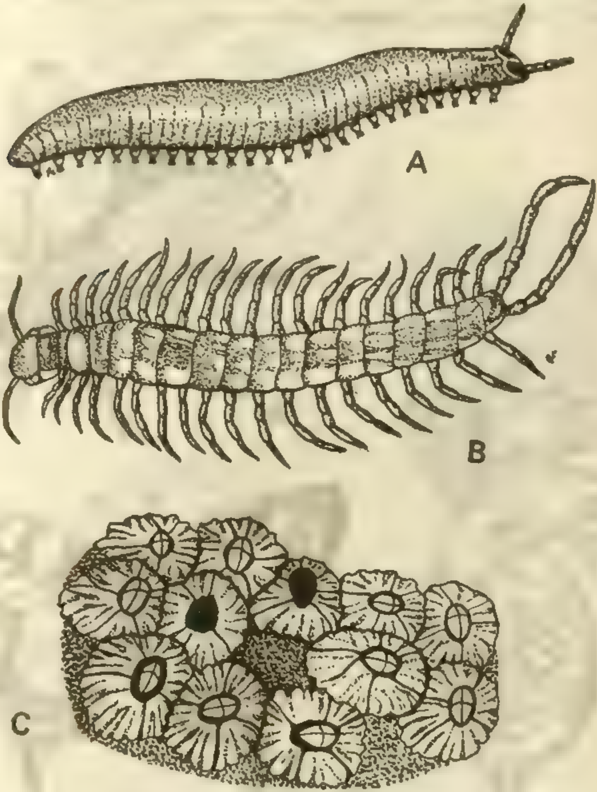


Fig. 11. A—*Peripetus*, B—Centipede, C—Barnacles (*Balanus*).

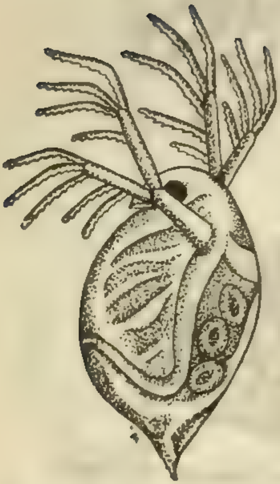
4. **Bivalvia**—Soft body is enclosed by the shell which have two valves or halves (Fig. 15B & C), e.g., *Unio*, *Anodonta*, Venus shell, Pearl oyster, Giant Clam (Fig. 15B), etc.

5. **Cephalopoda**—Head well developed bearing a pair of eyes and tentacles, shell external, internal or none, e.g., Squid, *Sepia* (cattle fish) (Fig. 16), *Octopus*, etc.

Phylum 9. **Echinodermata** (Greek: *Echinos*—spine, *derma*—skin).

Spiny skinned, sluggish animals. Body radially symmetrical when adult. These animals have many small tube like feet (tube feet). Locomotion is exhibited by tube feet. Body unsegmented,

endoskeleton spiny and is composed of calcium carbonate plates. The body of the animal may be spherical elongated, star shaped or feather like in shape. Part of the body cavity is converted into a system of water containing vessels (the water vascular system). Waste materials are excreted through the gills and tube feet. Unisexual, fertilization external, all marine.



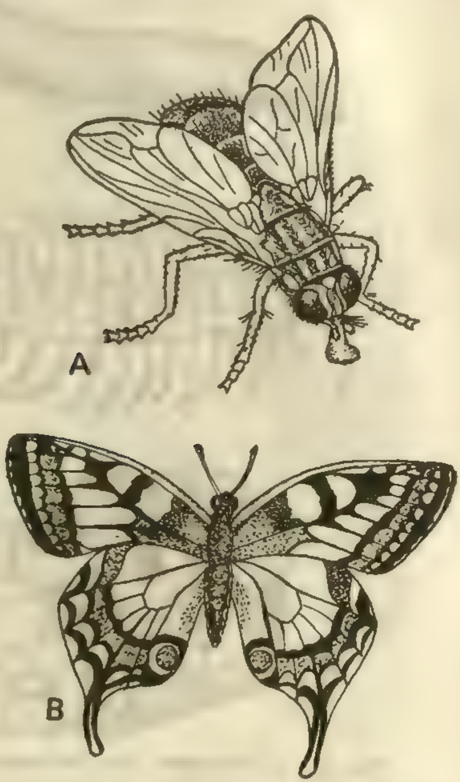


Fig. 12. *Daphnia* (highly *magnified*). Fig. 13. A—Housefly, B—Butterfly.

This phylum is divided into a few classes namely:

1. **Asteroidea** have a central disk, the arms can not be clearly differentiated from the body, e.g., starfishes (Fig. 17B). 2. **Ophiuroidea**—These animals have a clearly demarcated central disc., e.g., brittle stars (Fig. 17A). 3. **Echinoidea**—Globular, flattened forms and have no arm, e.g., Sea urchin. 4. **Crinoidea**—Flower like, mouth is in the centre of the calyx and is surrounded by arms, e.g., Sea lilies. 5. **Holothiuroidea**—Body elongated, e.g., Sea cucumber (Fig. 17C).

Phylum **Chordata** (Greek : *Chorda*—cord)

Body bilaterally symmetrical. Chordates are most advanced animals. All chordates possess a stiff axial rod, the notochord (chorda dorsalis), at least at one stage of their development. Presence of notochord is an important feature and from this

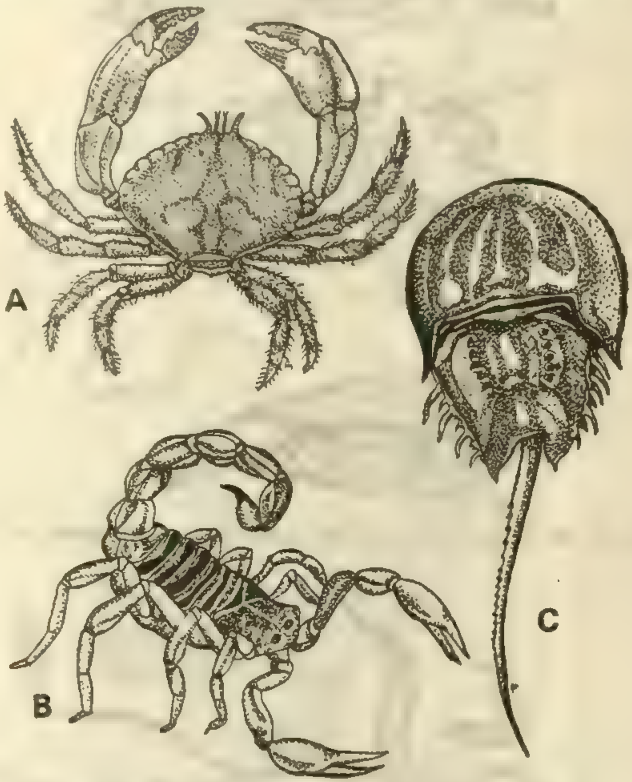


Fig. 14. A—Crab, B—Scorpion and C—King crab.

(notochord) the name of the phylum has been derived. Notochord is a long flexible cord extending from head to tail along the dorsal midline and is made up of vacuolated cells. It occurs between the dorsal cord of the central nervous system and the alimentary canal and acts as a skeletal support. The nervous system is composed of a hollow tube, the spinal cord, which lies on a dorsal position and a brain at the anterior end. Blood vascular system is well developed in Chordates. They have a distinct body cavity (coelom). The most simple type of Chordates have no skull.

The chordates are divided into 4 subphyla namely, Hemichor-

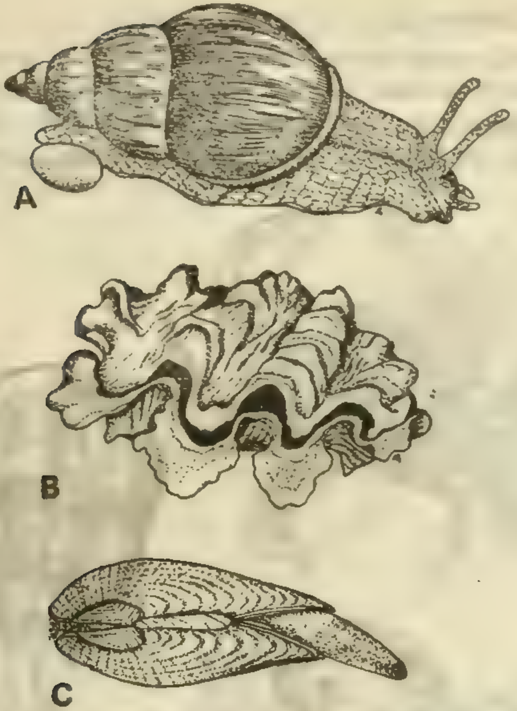


Fig. 15. A—Giant land snail, B—Giant Clam, C—Common Piddock.

Fig. 16. A—Giant squid, B—Sepia.

data, Urochordata, Cephalochordata and Vertebrata or Craniata. The chordates belonging to the first three subphyla have no skull or vertebral column.

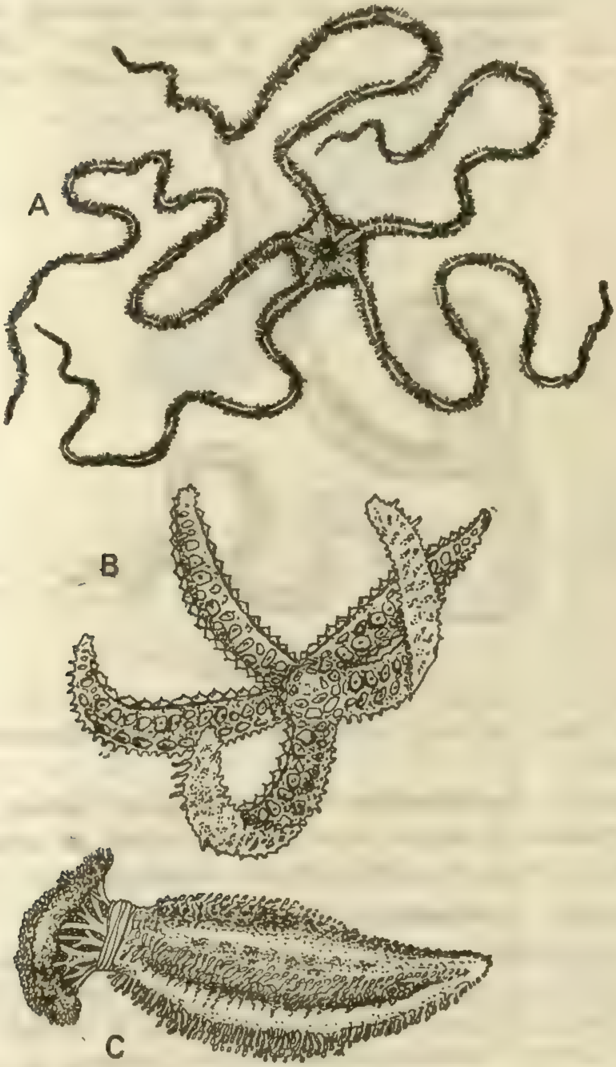


Fig. 17. A—Brittle star, B—Starfish, C—Sea cucumber.

Sub-phylum 1. **Hemichordata** (or **Adelochordata**)

Notochord is very small and occupies a small part of the body. It is considered to be a primitive type of notochord and is

sometimes called as *stomochord.* The body is differentiated into three regions. Hemichordates are marine. This sub-phylum is divided into two classes, namely, Enteropneusta and Pterobranchia.

Class 1. **Enteropneusta**—Marine, worm-like, burrowing animals; body soft, cylindrical. The body is divided into 3 regions—(a) anterior—proboscis for burrowing, (b) middle—collar with mouth

Fig. 18. *Balanoglossus.*

and (c) posterior—long, cylindrical trunk, e.g., *Balanoglossus* (Fig. 18).

Class 2. **Pterobranchiata**—Sessile, polyp-like animals. They are surrounded by tubular protective cases, which are attached to the floor of the sea, e.g., *Cephalodiscus, Rhabdopleura.*

Sub-phylum 2. **Urochordata** (or **Tunicata).**

The notochord is absent in adult stage but present towards the tail in embryonic stage. A dorsal hollow nerve cord is also present in the tail region only. This subphylum is divided into 3 classes, namely, Ascidacea, Thaliacea and Larvacea (or Appendicularia).

1. **Ascidiacea**—(Sea squirts) have sac like bodies corvered by a hard case, e.g., *Ascidia.* 2. **Thaliacea**—Free swimming plaktonic forms e.g., *Salpa.* 3. **Larvacea** or **Appendiculeria**—Free swimming planktonic forms; e.g., *Fritillaria, Appendicularia.*

Sub-phylum 3. **Cephalochordata** (or **Acrania**)

Sand burrowing animals of shallow coastal waters. The notochord extends from head to tail. The body is pointed at both ends.

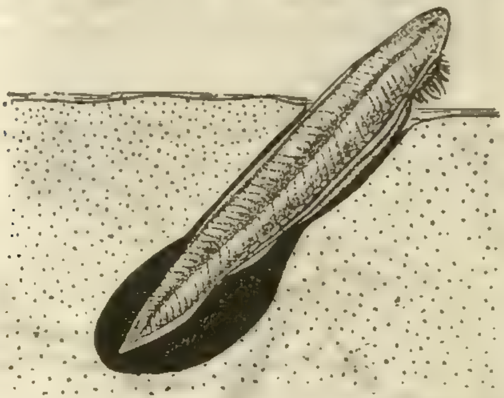


Fig. 19. -*Amphioxus*.

These animals can swim actively. Unisexual animals having external fertilization. Only one class, **Leptocardii** e.g., *Amphioxus* (Fig. 19), *Asymmetron*.

Sub-phylum 4. **Vertebrata** (or **Craniata**).

Notochord is present in the embryonic stage but at later stages the notochord is transformed into vertebral column. On account of the presence of vertebral column the animals are called vertebrates. Vertebrates are divided into two super classes, namely: 1. Agnatha and 2. Gnathostomata.

Super class **Agnatha**—Vertebrates without jaws belong to this group. The mouth is circular with pointed teeth. Such jawless animals are often grouped under the class **Cyclostomata** (cyclo—round, stoma—mouth). In these primitive types of vertebrates the notochord and vertebral column are present. Usually marine.

Only a few animals of this class are now existing. The living jawless fishes are the hagfishes (*Myxine*) and lampreys (*Petromyzon*). The hagfishes (Fig. 20B) are blind and have antenna like whiskers around their mouth. Lampreys (Fig. 20A) are usually parasitic with a sucking mouth. In larval stage they are blind but possess eyes in adult stage.

Super class **Gnathostomata** (*Gnatho*—jaw, *stoma*—mouth)

Animals of this super class have hard upper and lower jaws so they are known as jawed animals. All animals from fish to mammals belong to this group. Gnathostomata are divided into six classes. 1. Chondrichthys. 2. Osteichthyes. 3. Amphibia. 4. Reptilia. 5. Aves. 6. Mammalia.

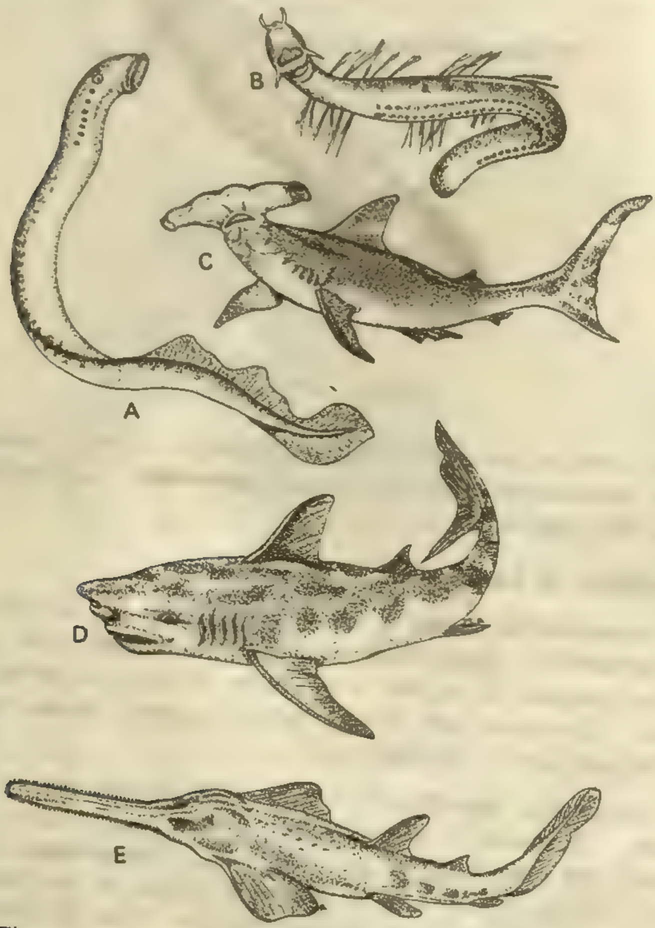


Fig. 20. A—Lamprey, B—Hagfish, C—Hammerhead shark.

Class 1. **Chondrichthyes** (*Chondros*—cartilage, *ichthys*—fish)

Marine fishes having a skeleton of cartilage belong to this class. So they are known as cartilagenous fishes. These animals have paired pectoral and pelvic fins and various types of additional dorsal, anal and ventral fins. The skin is covered by small, stiff

scales—the placoids. The heart is four chambered. Mouth is situated on the ventral side of the head. Respiration takes place with the gills. Operculum is absent.

They are cold blooded animals (poikilothermous), that is their body temperature depends on the environmental temperature. This class includes largest fishes, namely, the whale shark (45 feet long) and giant basking sharks e.g., Sharks (*Scoliodon*) (Fig. 20C & D), Electric ray, Sawfish (Fig. 20E), etc.

Class 2. **Osteichthyes** (*Osteon*-bone, *ichthys*-fish).

The skeleton is entirely bony. (In some primitive forms the endoskeleton is cartilagenous but have a cranium of bony plates). The body is covered by scales, which are known as *cycloid* or *ctenoid*. The mouth is situated towards the anterior side. Paired and unpaired fins are present. These fins have finrays. Gills and operculum are present. They are cold-blooded animals.

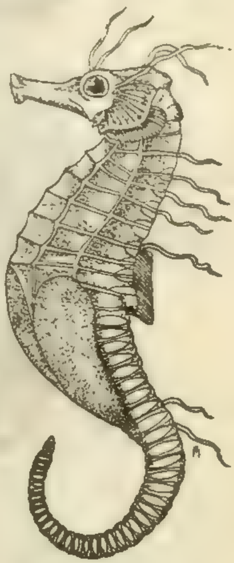


Fig. 21. Sea Horse.

The primitive bony fishes are grouped under Paleopterygi and the modern bony fishes belong to the group Neopterygi. The Paleopterygi include three families: the birchirs, the sturgeons and the paddle fishes. The modern bony fishes are more or less similar in their external appearance but the position and number of their fins varies. These fishes are either soft or spiny rayed. Internally, the shape of all vertebrae are similar and anterior bone is modified into weberian apparatus, e.g., Sea horse (*Hippocampus*) (Fig. 21), *Clarias, Lobeo, Catla, Anabas* (Fig. 22), *Lates*, etc.

Class 3. **Amphibia** (Greek: *Amphi*—both, *bios*—life)

As these cold-blooded animals can live in aquatic and terrestrial conditions they are called amphibians. They are the first vertebrate which become adapted to land life. Animals beloñging to this group are aquatic during the early part of their life, but terrestrial in adult stage. But few amphibians are aquatic throughout their life cycle.

These animals have no scale. They have a pair of fore limbs and a pair of hindlimbs. They respire with the help of skin and

gills in various larval stages and with lungs when adult. Their heart is made up of two auricles and a ventricle. The skull is attached to the vertebral column in such a way so that it can move (movably attached).

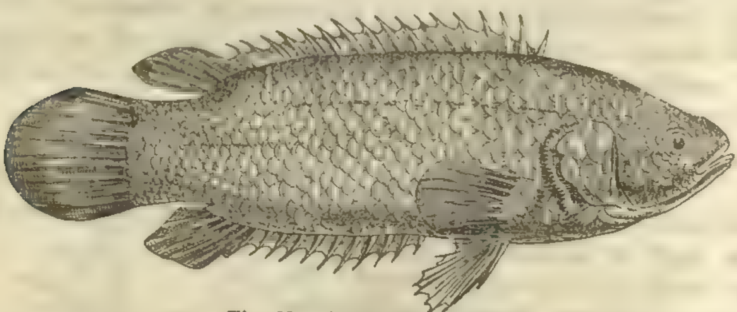


Fig. 22. *Anabas* (B. Koi).

There are three sub-classes of amphibia ; 1. **Apoda**—tropical legless, worm like, burrowing forms. 2. **Urodela**—tailed amphibians, e.g., Newts and Salmanders (Fig. 23). 3. **Anura**—tailless amphibians, e.g., Frog. Toad (Fig. 24), etc.

Fig. 23. Salamander.

Class 4. **Reptilia** (Latin : *Reptilis*—creeping)

Terrestrial cold-blooded animal that crawls or moves on its belly or by means of small, short legs. Some are aquatic (e.g., Crocodile, Tortoise) but they lay their eggs on land. They respire with the help of lungs. The body is covered by horny scales. The epidermis is hardened and cornified and sometimes forms a considerable amount of horny material that accumulates forming a protective covering such as, the scutes of "tortoise shell" in turtles. Fingers are provided with claws. The heart is three chambered except in crocodile. The young reptile resembles the adult form and does not pass through the larval stage; e.g., House

lizard (*Hemidactylus*), Calotes, Chameleon, Snakes, Crocodile, *Alligator*, etc.

There are several kinds of reptiles that exist, namely :

1. **Chelonians** have a box like armour beneath which head, limbs and tail can be withdrawn for security, e.g., turtles, *Chelonia* (green turtle), *Testudo* (Greek tortoise) (Fig. 26).

Fig. 24. A toad (*Bufo melanosticus*).

2. **Lacertilia** or *Lizards*—modern group of reptiles. They have a moveable eyelids, visible eardrum and small scales on the ventral surface, e.g., *Draco* (flying lizard), Gila monster (Fig. 25), etc.

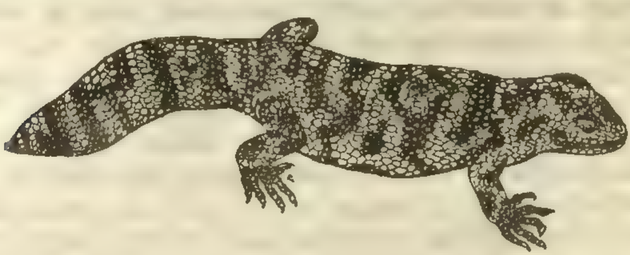


Fig. 25. Lizard, Gila monstar.

3. **Ophidia** or *snakes*—Limbs much reduced, external eardrum and moveable eyelids absent, there is one row of wide over-

lapping scales on the ventral surface, e.g., Cobra (Fig. 26), Python, etc.

4. **Crocodilians** have heavy body with a powerful tail and an elongated snout, e.g., *Alligator*, Crocodile (*Crocodilus*).

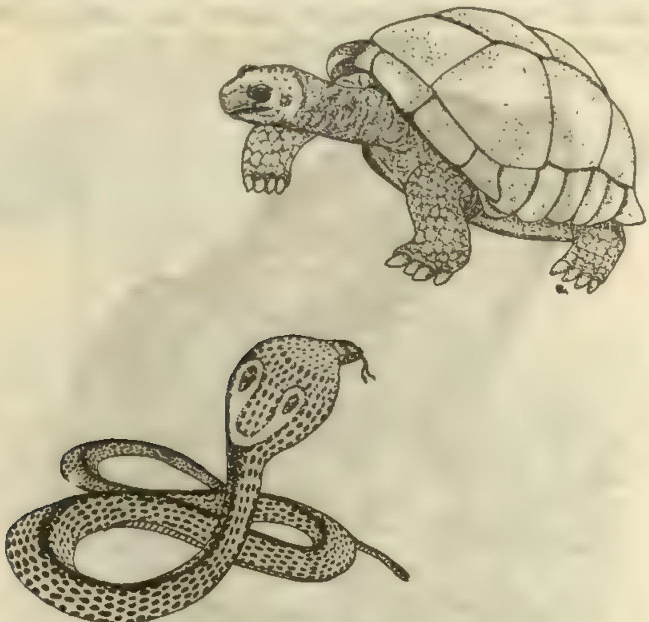


Fig. 26. Upper—tortoise, Lower—cobra.

Class 5. **Aves** (*Avis*—bird)

Warm blooded (homoiothermos) animals with beak. The body is variously modified in accordance with the aerial life. The body is covered by feathers. Their forelimbs are transformed to wings, with the help of which they can fly. Some birds, such as, ostrich, emu, etc. have small wings and so they can not fly. The heart has two auricles and two ventricles. They lay eggs. Although primitive birds had teeth, modern birds possess no teeth. The brain of birds is highly specialised. In modern birds the left aortic arch is absent. The lungs are extended into extra air sacs which are situated in air pockets in the neck and trunk bones. The skull is light and the teeth is replaced by light weight beak. Existing birds are divided into two divisions, namely, Ratitae and Carinatae.

Ratitae—Terrestrial, flightless birds having raft like breast bones, e.g., Ostrich (Fig. 27), Emu, Kiwi, Rhea, Cassowary, etc. Ostrich

is the largest existing bird with long legs and well developed thigh muscles, found in Africa and S. W. Asia. Emu is found in Australia, Kiwi in New Zealand.

Carinatae have wings adopted for flight except the penguins. The wings of penguins are transformed into rowing paddles. Penguins are found in Antartica and Southern Hemisphere. Some other birds under Carinatae are—Wood-pecker, Finch, Heron. Bird of paradise, Peacock, Hornbill (Fig. 28), Crow, Pigeon, Moina, etc.

Fig. 27. Ostrich, a flightless bird.

Fig. 28. Hornbill.

Class **Mammalia** (Latin : *mamma*—breast)

Most advanced animals. The body is at least partially covered by hairs. The characteristic feature of this group is the presence of mammary gland. These animals produce the young alive (viviparous). There are a few exceptions to this. The duck billed Platypus (a primitive mammal) lay eggs but the young ones feed on mother's milk. They usually form a filtering placenta between the maternal and embryonic tissues in the uterus and adopt special means for the protection and nourishment of new borns. As the young animals feed on mother's milk, they are said to be mammals. The external ear is provided with pinna.

They have four types of teeth, namely, incisor, canine, premolar and molar. So these animals are said to be heterodont (i.e. having various kinds of teeth). The thorax and abdominal cavity

is separated by muscular diaphragm. The brain (particularly forebrain) is comparatively large. They are warm blooded animals

Fig. 29. Platypus, an egg laying mammal.

with four chambered (two auricles and two ventricles) heart, e.g. Whale (Baleen), Bat, Guineapig (*Cavia*), Kangaroo (*Macropus*), *Rhinoceres,* Man (*Homo sapiens*) etc.

There are three groups of mammals:

(a) **Monotremes** unlike other mammals lay eggs. They are found in Australia, New Guinea and Tasmania, e.g., Duck billed platypus (Fig. 29), Spiny ant-eaters, etc.

Fig. 30. Kangaroo, marsupial mammal.

(b) **Marsupials** or pouched mammals. The embryo is born in a very underdeveloped condition, which later deve-

lops within the mother's pouch, where they may remain for several months. Usually found in Australia, e.g., Kangaroo (Fig. 30), Koala (a bear like arboreal marsupial), Tasmanian wolf, Marsupial mole, Rat kangaroo, etc.

Fig. 31. Spotted deer (Chital).

(c) **Placental mammals**—They develop a placenta in the uterus. The young ones are retained within the uterus and get food and oxygen from the mother, e.g., Bats, Sea cows, Whale (*Baleen*), Dolphin, Camel, Cat, Dog, Cow, Deer, (Fig. 31), Fox, giant Ant eater, Lemur, Gorilla, Monkey, Man, etc.

2

STRUCTURE AND FUNCTIONS OF AMOEBA, TAPEWORM AND GUINEAPIG

AMOEBA

It is a very small and simple unicellular animal. There are several species, of which the large species *Amoeba proteus* is usually studied. It is generally found in slow moving fresh water, especially on mud at the bottom of ponds, tanks and such other places where there is plenty of aquatic vegetation. When the specimen of *Amoeba* is quite large they appear as white dots to the naked eye.

Amoeba (Fig. 32) appears as a colourless, irregular, mass of jelly like substance continually changing its shape. Its size varies from 0.1 mm to 0.25 mm. The body of the *Amoeba* is completely surrounded by a delicate outer limiting membrane, known as plasmalemma or plasma membrane. Below this there is a clear thin layer

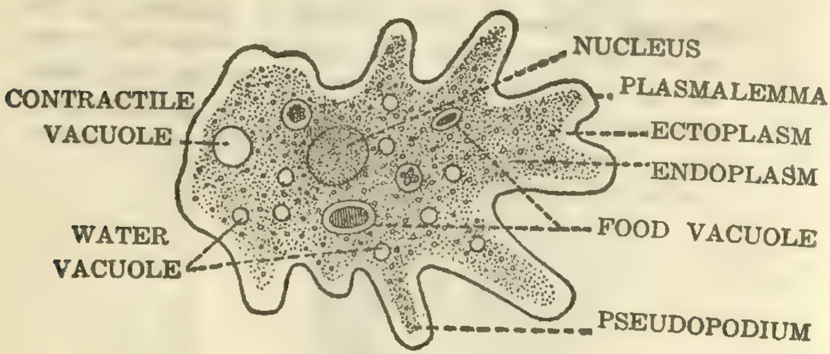


Fig. 32. *Amoeba proteus.*

of cytoplasm—the *ectoplasm*. Inside this there is a granular mass of cytoplasm, called the *endoplasm*. Within the endoplasm a single nucleus and several vacuoles are found. The shape of the *Amoeba* is constantly changing because from its body numerous projection of varying length are thrown out. These processes are known as *pseudopodia* (Greek : *pseudes*—false, *podus*—foot).

Nucleus—The nucleus which controls all the activities of the animal is spherical in shape. Only one nucleus is present in each *Amoeba* (i.e., uninucleate). It contains chromatin granules and is surrounded by a nuclear membrane. In a stained preparation it appears brighter than the surrounding endoplasm.

Vacuoles—Usually three types of vacuoles are found in *Amoeba*. These are *food vacuoles, water vacuoles* and *contractile vacuoles*. (a) **Food vacuoles** contain food particles and drops of water. These vacuoles exist as long as the food particles remain (i.e., digested and absorbed) inside the body and disappear with the egestion of the undigested waste from the body. (b) **Water vacuoles** are small, round vacuoles containing clear drops of water. The size of these vacuoles usually does not change. (c) **contractile vacuoles**—They appear as water vacuoles but unlike water vacuoles they change their size. Due to the high concentration of the dissolved substances in protoplasm water enters through the plasma membrane inside the cell by the process of osmosis. The contractile vacuole collects excess water and enlarges to a maximum size. This vacuole then moves towards the plasma membrane. After reaching the surface it brusts ejecting water and some dissolved waste materials and finally disappears. This process of altermately filling and contracting is repeated. Thus the main function of the contractile vacuoles is to regulate the water content of the body. In addition to this, they also serve as excretory and respiratory organs.

Endoplasmic inclusions—Besides the nucleus and various types of vacuoles described above the endoplasm contains many granules of varying sizes and shapes. These may be either foreign substances (e.g., sand particle) or certain products of metabolism, such as, stored food or excretory substances.

Amoeboid movement

Amoeba carries on its locomotion by means of pseudopodia (Fig. 33). The protoplasm of the endoplasm of *Amoeba* exists in two forms, namely, plasmagel and plasmasol. Just inside the ectoplasm there is a firm jelly like mass of endoplasm, this is known as plasmagel. Inside the plasmagel the endoplasm exists in a more fluid state, which is known as plasmasol. The plasmagel and plasmasol can be changed into each other and thus provides a means by which an *Amoeba* can exhibit locomotion.

If at any region of the body due to changes in two states, the surface tension diminishes and the jelly like mass cannot be held

together then a portion of the body substance flows from that region to form a pseudopodium. The pseudopodium lies within the plasma membrane. The central part of the endoplasm gradually flows towards the pseudopodium more and more and as this onflow continues it pushes the advancing pseudopodium. The tips of the pseudopodia probably exert some adhesive force on the substratum and cause the other end to be drawn towards them. In this way the *Amoeba* glides along the substratum. Pseudopodia which are not in contact with any substratum can not effect locomotion.

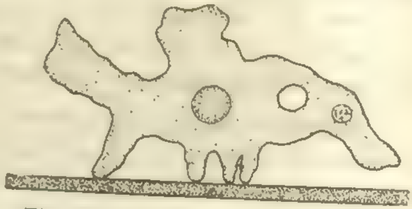


Fig. 33. An *Amoeba* showing gliding movement on a substratum by pseudopodia.

Nutrition—The food of an *Amoeba* consists of bacteria, algae, (such as, diatoms) and some protozoa. Food particles secretes certain chemicals into water. An *Amoeba* becomes attracted by such chemicals and forms pseudopodia in that direction. These pseudopodia grow out and ultimately surround the food particle (Fig. 34) completely. Then the food together with a drop of water is taken inside the body and thus a food vacuole is formed. This process is known as *ingestion*. Into this food vacuole the protoplasm secretes enzymes, which help the *digestion* of the food. As the digestion proceeds the digested food passes into the fluid of the food vacuole and from there it goes into the surrounding protoplasm.

Fig. 34. Ingestion of food by *Amoeba*.

This process is known as *absorption*. The food vacuole may circulate to all parts of the body and the digested food is incorporated into the body substances. Some amount of food substance may not be required immediately and this may remain as stored food in the endoplasm. The undigested part of the food particle is eliminated out of the body by a process which is known as *egestion* and the animal glides away leaving the faeces.

Excretion—In *Amoeba* during the course of metabolism waste products are formed. These waste products are collected in the contractile vacuole and are ultimately eliminated out of the body. But crystals representing excretory substance may remain in the endoplasm. Nitrogenous wastes and carbon dioxide, etc. may diffuse out of the body through the plasma membrane, as the concentration of these wastes are higher inside the cell than outside.

Respiration—Respiration generally takes place throughout the body surface but some amount of carbon dioxide may be expelled through the contractile vacuole. There is a high concentration of dissolved oxygen in the surrounding water in comparison to the low oxygen concentration of the protoplasm. As a result of this, oxygen diffuses through the plasma membrane inside the cell. This oxygen is used in respiration as soon as it enters within the cell. Carbon dioxide is produced during respiration and its concentration being higher inside the cell than the surrounding medium it diffuses out through the plasma membrane.

Irritability—An *Amoeba* responds to various stimuli. It moves towards a food particle. The potential food secretes chemicals into water and an *Amoeba* is attracted by these chemicals and moves towards the food particle. The *Amoeba* moves away from substance and chemicals (e.g., acid) which tend to injure it. It also avoids too strong light. Extreme cold or heat (temperature above 30°) will retard the activities of an *Amoeba*. During unfavourable conditions the various functions of life of an *Amoeba* is retarded or slowed down. This stage is known as *depression*.

Dormancy and Encystment—During unfavourable conditions, such as, extreme temperatures, drought, etc., when the *Amoeba* is threatened to death, it withdraws all pseudopodia and rounds off. Then the protoplasm secretes a thick, hard wall around the body either forming a single *cyst* or its contents breaks up (multiple fission) forming several spores within a cyst. The process of cyst formation is known as encystment, which enables the *Amoeba* to overcome the unfavourable condition. In this cyst condition, the *Amoeba* may be carried to a favourable situation, then the cyst bursts, the *Amoeba* emerges and begins its active life.

Reproduction—Where there is an excess of food over the immediate needs, the body volume enlarges and reaches a limiting size. When the body volume becomes large enough in relation to the surface area, then reproduction takes place. Reproduction usually takes place by binary fission.

Binary fission—Binary fission (Fig. 35) is the process by which one cell splits and forms two cells. During this process the body of the *Amoeba* elongates and the nucleus assumes a dumb-bell shaped structure which gradually narrows down in the middle and

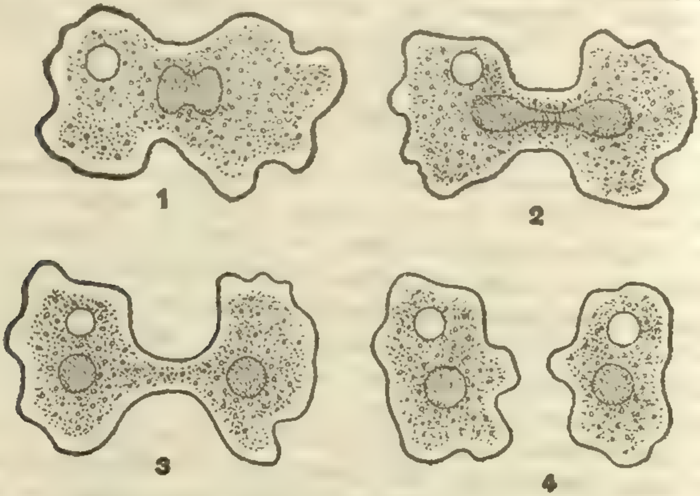


Fig. 35. Stages of binary fission in *Amoeba*.

finally divides into two nuclei. A constriction now appears in the middle of the body. This constriction gradually increases and ultimately the body is divided into two, each of which receives a nucleus. In this way an *Amoeba* gives rise to two smaller individuals each of which again performs all the vital activities (nutrition, growth, movement, etc.).

Fig. 36. Stages of sporulation and encystment in *Amoeba*. 1—Nuclear fagmentation. 2—Formation of pseudopodiospores.

Multiple fission or sporulation (Fig. 36)—It is another method of reproduction, which takes place during unfavourable conditions

(see also encystment). The portoplasm rounds off and is surrounded by three layers forming a cyst. The nucleus then divides into a number of fragments. Then the cytoplasm also divides into a number of parts, each part surrounds a nucleus. Thick resistant walls are formed around the cytoplasm. In this way a number of spores are formed. These spores are sometimes called *pseudopodiospores*. When the conditions become favourable the wall of the cyst breaks liberating the spores. Each spore develops into a small *Amoeba*.

Plastogamy—Occasionally several *Amoeba* come together, their cytoplasm fuse forming a single mass, in which the nuclei remain scattered. Such a mass formed by the fusion of several individuals is known as a *plasmodium* and the process is known as *plastogamy*.

TAPEWORM

Tape worms are parasites with a long dorsiventrally flattened body and belong to the phylum Platyhelminthes. As their body are tape like, they are commonly called tape worms. The most common representatives of tapeworm are *Taenia solium* (pork tapeworm) and *T. saginata* (beef tapeworm). *Taenia solium* occur as endoparasite in the human intestine. Man is the primary host of *T. solium*, the secondary host being pig. *Taenia* is cosmopolitan in distribution. The life history of *T. solium* is described below.

Structure

The flattened narrow, ribbon shaped body (Fig. 37) is 6-13 feet long and about one fourth inch broad. The anterior end of the body is attached with the intestinal mucosa of the host. Rest of the body remains free. The body is composed of three parts, namely, head or scolex, neck and body or strobila. The anterior side of the body is narrower than the posterior side.

(a) *Head or scolex*: The head is a small, knob-like structure situated at the anterior end. At the apex of the head there is a dome shaped projection, known as *rostellum*. Around the rostellum there are many recurved hooks. Besides these, four shallow, cup-shaped suckers are present on the lateral surface of the head. The rostellum can contract and expand. During contraction of the rostellum the hooks extend forward and penetrate in the host tissue. During expansion of the rostellum the hooks bend backward and thus attach the parasite firmly with the intestinal mucosa of the host. The suckers also help the parasite to attach itself with the intestinal tissue.

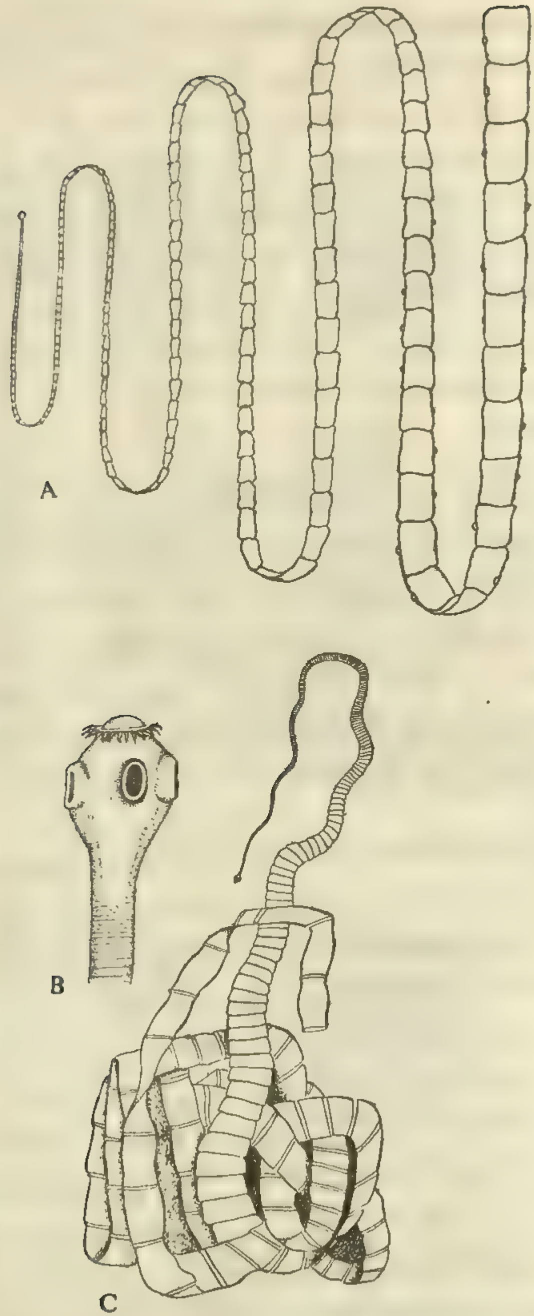


Fig. 37. External structure of *Taenia solium* (tapeworm), A—in expanded condition, B—head, C—in natural condition.

(b) *Neck*: It is a narrow unsegmented part and is the region of proliferation. Proglottids develop from this region.

(c) *Body or strobila*: It is a long, much segmented part. Each segment is known as proglottid. The number of proglottids varies from 800-850. The proglottids near the neck are comparatively smaller and younger, whereas those far away from the neck are comparatively larger and older. The young (immature) proglottids have undeveloped sex organs. The mature proglottids found at the middle region of the body have well developed male and female sex organs. The proglottids near the end of the body (ripe or gravid proglottid) are largest (Fig. 38) and contain much branched uterus filled with eggs.

Each mature proglottid (Fig. 39) is covered by a layer of cuticle. Beneath the cuticle there is a hypodermis, subjacent to which there is a well developed muscular tissue consisting of upper and lower longitudinal muscle fibres and a middle region of circular muscle fibres. The remaining part (medulla) of the proglottid is filled up with the mesenchyma on which various organs, such as, male and female reproductive organs, excretory organs, etc. are situated.

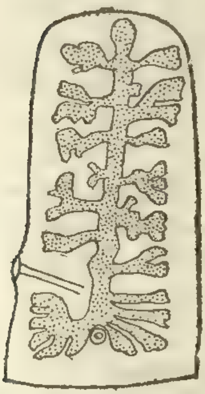


Fig. 38. A ripe proglottid of *Taenia*.

Digestive system is absent in *Taenia* and it absorbs prepared food from the intestine of man. *Taenia* respires both aerobically and anaerobically as it lives in small intestine where there is little oxygen.

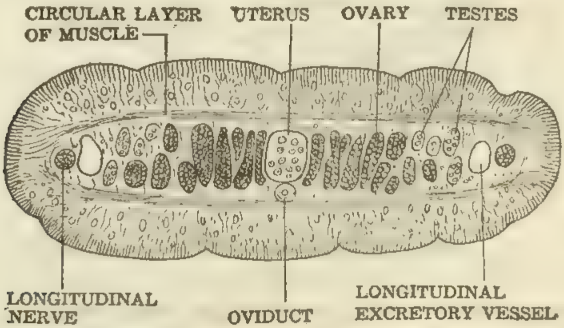


Fig. 39. Transverse section of a proglottid of *Taenia solium*.

Excretory system

It consists of two longitudinal canals which extends through the whole tapeworm. In each proglottid these two longitudinal excretory canals are connected by a transverse excretory canal, which is situated at the posterior part of the proglottid. The excretory canals have a number of branches, which in their turn give origin to many fine capillaries, which are ultimately connected with the flame cells. The excretory substances enter in the excretory canal from the flame cells. The longitudinal excretory canals in the last proglottid ends in a sac-like caudal bladder which is connected by a duct with the exterior.

Nervous system

The nervous system consists of two ganglia situated in the head. The ganglia are connected by slender nerves forming the transverse commissure. Nerves arise from the ganglia and enters in the sucker and rostellum. From each ganglia a longitudinal nerve arises and run backwards through the proglottids to the posterior end of the body.

Reproductive organ

The male reproductive system is situated in the anterior part of the mature proglottid. It consists of many rossette like testes, each of which is attached with a slender vas efferens. All these

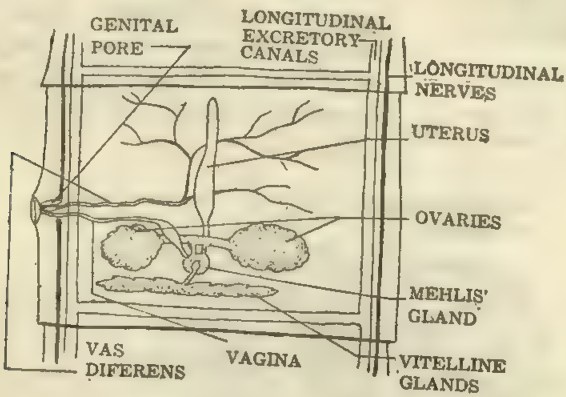


Fig. 40. A proglottid of *Taenia* showing mature reproductive organs.

vas, efferentia fuse and form a much convoluted vas deferens, which is transversely placed. The vas deferens ends in a unconvoluted cirrus, which in its turn terminates in a cup shaped genital

atrium. The genital atrium opens externally through a genital pore.

The female reproductive system (Fig. 40) is found in the posterior part of the mature proglottids. It consists of ovary, ovarian isthmus, oviduct, vagina, seminal receptacle, ootype, shell glands, vitelline duct, vitelline glands and uterus. The ovary is trilobed. Each lobe composed of many radiating follicles and is connected with a slender tube like ovarian isthmus. The ovarian isthmus are connected with a oviduct, which extend towards the posterior side. This oviduct is connected with the genital pore by a long slender duct, the vagina/ Just near the attachment with the oviduct it dilates forming the seminal receptacle. The fusion of the vagina and oviduct culminates in the formation of a broad ootype which is surrounded by unicellular shell glands. The ootype also receives the vitelline duct which is connected with the vitelline glands situated on the posterior part. An elongated uterus extending into the anterior part of the proglottid is connected with the ootype. In the ripe or gravid proglottids found in the posterior region of the body the uterus becomes much branched and large and fills the major part of the interior of the proglottid (Fig. 38). The other reproductive structures being absorbed in the meantime.

Fertilization

Self-fertilization takes place in *T. solium*. Numerous sperms possibly from the same proglottid pass through the vagina to the seminal receptacle. The eggs from the ovary come to the ootype for fertilization. Now sperms from the seminal vescicle pass through the oviduct to the ootype and fertilise the eggs. Each fertilised egg is covered by the secretion of vitelline gland (yolk gland). It is covered lastly by the secretion of the shell glands. This secretion forms a shell around the fertilised egg. At this stage the fertilised eggs enter in the uterus where they accumulate in thousands. Ripe or gravid proglottids contain much branched uterus with numerous eggs.

Development

The fertilized eggs (zygotes) develop within the uterus. At first the zygote divides forming two unequal cells. The larger cell is known as *megamere* and the smaller cell as *embryonic cell.* These two cells divide repeatedly forming large numbers of cells. The embryonic cell forms the embryo. The cells formed from megamere form a protective covering around the embryo and these

covering is known as *embryophore*. The embryo now develops six hooks and is known as *hexacanth*. At this stage the embryo with the protective covering and egg shell is called *oncosphere*. The ripe proglottids when detached, pass with the faeces of the host to the exterior. If the proglottids or the oncosphere are taken by the pig, which forms the intermediate host, then the hooked embryos come out of their coverings and pass through the wall of the alimentary canal and ultimately reach the voluntary muscles. They then increase considerably in size and are

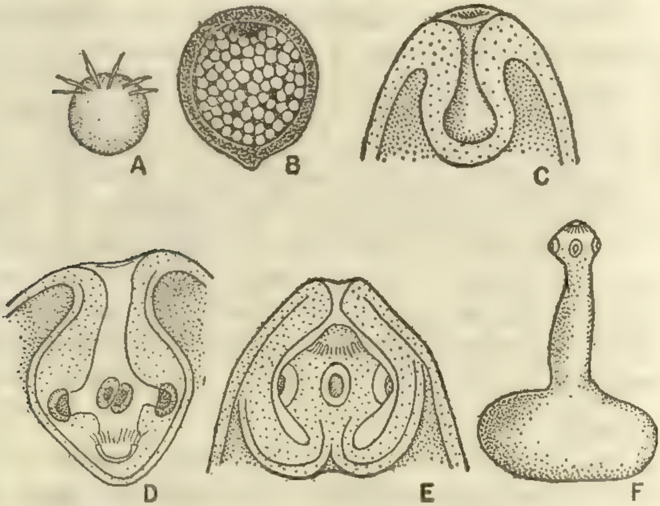


Fig. 41. Stages of development of *Taenia;* A—six hooked embryo (hexacanth), B—early stage of bladderworm. C—E stages in the formation of head (scolex), C—invagination before the formation of hooks and suckers, D—after the formation of hooks and suckers, E—partly evaginated, F—fully evaginated head and caudal vescicle of *Taenia*.

transformed into rounded cysts. The central part of the cyst is filled with watery fluid. The embryo now looks like a bladder. On the wall of the bladder a hollow ingrowth is formed on one side. On the inner surface of the ingrowth hooks and suckers are formed. After this the hollow ingrowth inverts and the whole structure now becomes the typical head of a tapeworm (Fig. 41) with hooks on the outer surface and suckers. The bladder like embryo at this stage has the characteristic head and neck of *T. solium*. This stage is known as *bladderworm* stage or *cysticercus*. When pig meat containing cysticerci is taken by man in unboiled or half boiled condition then the parasites find their way

into human body. The wall of the cysticercus breaks and the head with its hooks and suckers becomes attached to the intestinal wall and forms a series of proglottids. Thus an adult tapeworm is formed. In properly boiled and cooked meat the cysticerci are killed.

The life cycle of tapeworm is shown in Fig. 42.

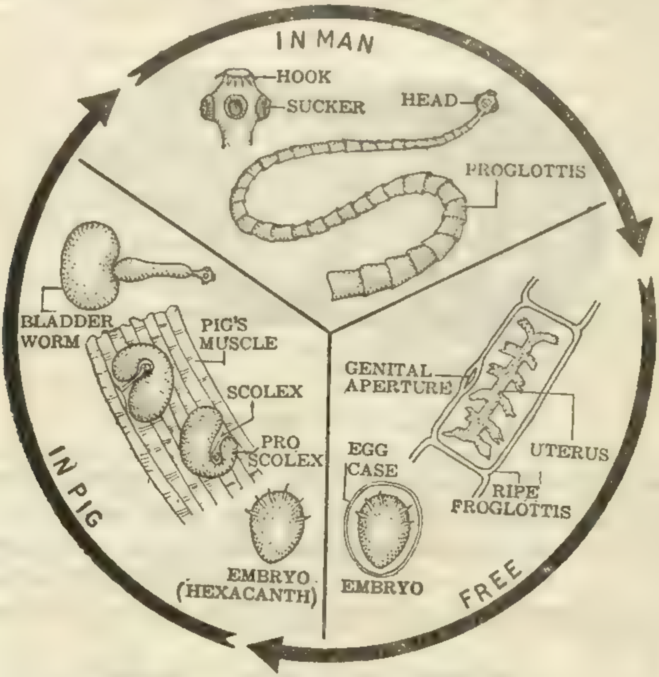


Fig. 42. Diagram showing the life cycle of *Taenia.*

GUINEAPIG

Guineapig belongs to the order Rodentia under the class Mammalia. Generally the animals which have sharp exposed incisors are known as rodents. All general characteristics of mammalia are found in guineapig. The animal is herbivorous in habit. The scientific name of guineapig is *Cavia porcellus.*

Phylum—Chordata; Class—Mammalia; Sub-Class—Eutheria; Order—Rodentia.

External characters

The body of guineapig is covered with hairs. The body is divided into three regions—the head, neck and the trunk (Fig. 43).

Some stiff hairs known as *vibrissae* are present on the snout. The mouth is bounded by lips of which the upper one is cleft in the middle exposing the incisor. The nostrils are a pair of oblique slits just above the mouth. A pair of eyes are placed on the sides of the head. These are provided with upper and lower eyelids and another membranous covering known as nictitating membrane. By the side of the external auditory aperture of each side is

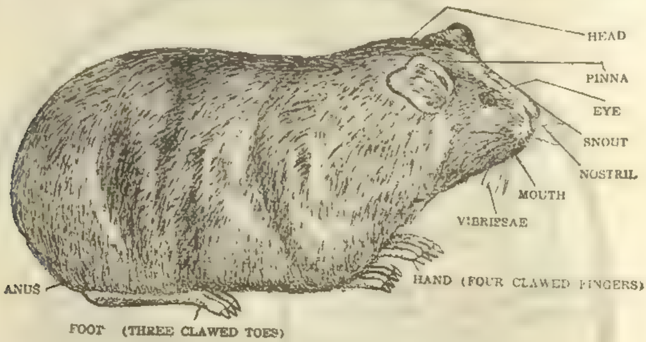


Fig. 43. External feature of Guineapig.

situated the flexible expanded ear lobe known as *pinna*. The neck is short and flexible. The trunk consists of an anterior thoracic and a posterior abdominal region. The teats, usually two in number, are present on the ventral surface of the abdomen. The mammary glands open on the teats. These are well developed in the females.

The tail is practically absent being represented only by the root. The anus lies below the root of the tail at the posterior end of the abdomen. The urinogenital aperture is present anterior to the anus. In the male the aperture is situated at the end of a muscular cylindrical process—the penis. The penis remain retracted within a loose sheath of skin—the *prepuce*. During the breeding season the testis hang down on the sides of the penis in a pouch of skin known as *scrotum*. In the female the genital aperture known as *vulva* is slit like. The small fleshy process at the anterior margin of the vulva is known as *clitoris*. The urinary aperture is present just behind the clitoris. It is worth mentioning that in the male there is one common aperture for urinary and genital systems whereas in the female there are two separate apertures for urinary system and genital system. Of the two pairs of limbs, the fore limbs are shorter than the hind limbs. In each

fore limb there are four digits and in each hind limb there are three digits. Each of these digits terminate in a claw.

Body cavity

The body cavity or coelom is divided by a transverse muscular partition known as *diaphragm* into an anterior thoracic and a posterior abdominal portion. The diaphragm helps to induce the process of respiration and also brings about parturition i.e., childbirth. The body cavity is bounded by the vertebral column at the dorsal surface, the sternum at the ventral surface and by the ribs at the lateral surface. The inner side of the thoracic cavity is lined by a membrane which is known as *pleura.* Each lung is situated within the plural cavity. The heart is lined by the pericardium membrane and situated in between two plural cavities. The membrane which cover the inner side of the abdominal cavity is known as *peritonium.*

Skeletal system—The internal skeletal frame work is known as endoskeleton and is distinguished from exoskeleton which consists of the hard, protective external structure, such as, claws and hairs. These are epidermal in origin. The endoskeleton and the exoskeleton both are found in the guineapig.

Endoskeleton—The endoskeleton comprises the hard structures, such as, bones and cartilages. The endoskeleton of the body is grouped into (i) an axial portion lying along the longitudinal axis of the body (ii) an appendicular portion, which consists of bones supporting the limbs and limb girdles.

The axial portion of the skeleton consists of skull, vertebral column and the ribs.

Skull—The skull of guineapig is characterised by the presence of sutures or lines along which the edges of contiguous bones are united. The lower jaw is composed of two rami or pieces each of which is formed of a single bone (Fig. 44). The lower jaw directly articulates with the skull, the articular surface being longitudinally elongated. The angular process of the lower jaw is well-developed. The skull bears two occipital condyles for articulation with the vertebral column. The teeth are of different types and are placed in sockets.

The cranium proper consists of three segments—(i) anterior frontal, (ii) middle parietal, and (iii) posterior occipital. To the cranium are attached the three pairs of sense capsules and the jaw apparatus.

In the occipital segment at the posterior region of the skull, the large foramen magnum is situated. Surrounding this foramen there are the following four bones which become fused together in the adult condition: a supra-occipital above, a basi-occipital below and a pair of ex-occipitals on the sides forming the condyles. Each ex-occipital is produced below into a long and curved par-occipital process.

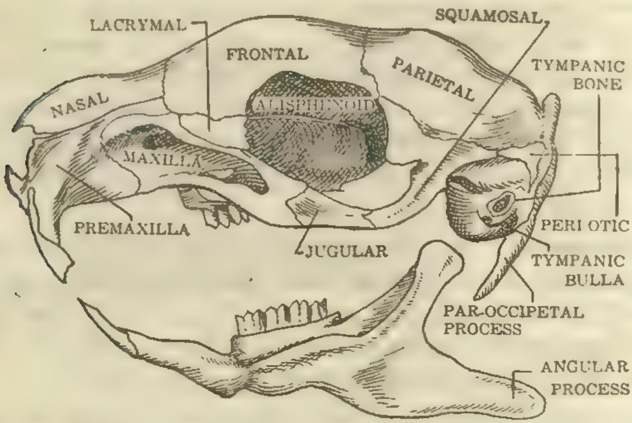


Fig. 44. Diagram showing the side view of skull and lower jaw of Guineapig.

In the parietal segment there are five bones; a pair of parietals above, one basi-sphenoid below and a pair of alisphenoids ventrolaterally. Between the parietals there is a small inter-parietal bone, the posterior border of which lies against supra-occipital.

In the frontal segment also there are five bones: a pair of frontals on the dorsal side, a laterally compressed presphenoid below and on the sides the two alisphenoids which are continued forward from the parietal segment. The outer border of each frontal forms a ridge along the upper margin of the orbit.

Auditory capsule of each side is situated between the parietal and occipital segments and consists mainly of a periotic bone. To the outer surface of this is attached the tympanic bone consisting of a tubular portion surrounding the external auditory meatus and below this a swollen portion known as bulla.

Olfactory capsule of each side is roofed by the narrow nasal

bone lying anterior to the frontal. The outer side of the capsule is guarded by the premaxilla anteriorly and maxilla posteriorly, whereas on the ventral side lies the vomer. The two vomers of the two capsules unite and form a single bone.

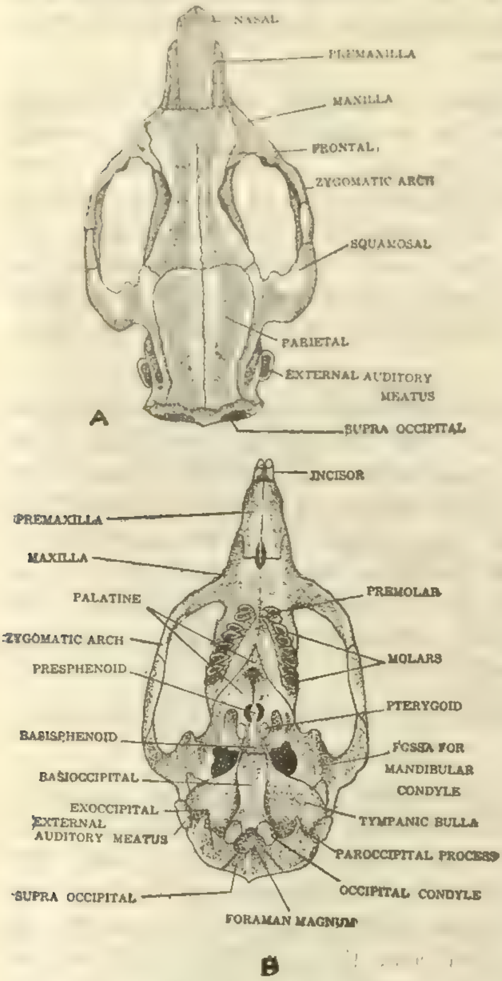


Fig. 45. Diagram of the skull of Guineapig ; A—Dorsal view, B—Ventral view.

The optic capsule of each side is guarded anteriorly by a lacrymal bone placed between frontal and maxilla.

The upper jaw on each side consists of a premaxilla anteriorly and a large maxilla posteriorly. The premaxilla bears the cutting (incisor) teeth and articulates anteriorly with its fellow of the opposite side in the middle line. The maxilla bears the cheek teeth (premolar and molars). From its inner edge is given off horizontally the palatine process, which, articulating with its fellow of the opposite side, forms the anterior part of the hard palate. From the outer side of the maxilla is given off a process, which forms the anterior part of the zygomatic arch extending below and external to the orbit.

Internal to the maxilla and attached to it in front, a thin vertical bone—the palatine lies nearer the middle line. An inwardly directed process arises from the anterior region of each palatine

and articulates with its fellow in the middle line forming the posterior part of hard palate. Attached to the posterior edge of each palatine is a small irregular bone—the pterygoid, produced into a backwardly curved process.

In front of each periotic, a plate of bone—the squamosal, completes the side wall of the cranium. It articulates anteriorly with frontal, parietal and alisphenoid. It is produced in front into a process which forms the hinder part of the stout zygomatic arch. This process and the process from the maxilla unite with an elongated bone—the jugal which constitutes the middle portion of the arch. The zygomatic process of the squamosal bears on its undersurface a longitudinal facet for the articulation of the lower jaw.

The lower jaw or mandible consists of two halves or rami which unite in front at the tips forming the symphysis. Each ramus is a vertical bone broad behind and tapering in front. The tapering end bears the incisor and on the upper margin of the broad end are the cheek teeth. Each ramus has at the hinder end an ascending portion bearing a condyle which fits into the facet on the undersurface of the process of the squamosal. The lower border of the posterior region in each ramus is produced into a well-developed angular process.

Hyoid is represented by a small bone situated at the root of the tongue.

Vertebral column—The vertebral column consists usually of 37 vertebrae. These are characterised by the possession of centra provided with epiphyses at both anterior and posterior ends. The anterior and posterior surfaces of the centrum are flat and between two successive vertebrae there is an intervertebral disc of fibro-cartilage. Each vertebra bears the neural arch and the pre- and post-zygapophyses. In the cervical or neck region there are 7 vertebrae. The 1st vertebra (atlas) is more or less ringlike and has at its anterior end two concave facets for articulation with the two occipital condyles (Fig. 46). The 2nd vertebra (axis) is peculiar (Fig. 46). Its neural spine is a large laterally compressed vertical plate which distinguishes it from all other vertebrae. In it the centrum is produced anteriorly into an *odontoid process* which rests on the floor of atlas ring and acts as pivot on which the head moves. The odontoid process of the axis is really the transformed centrum of the atlas. In the region of the thorax

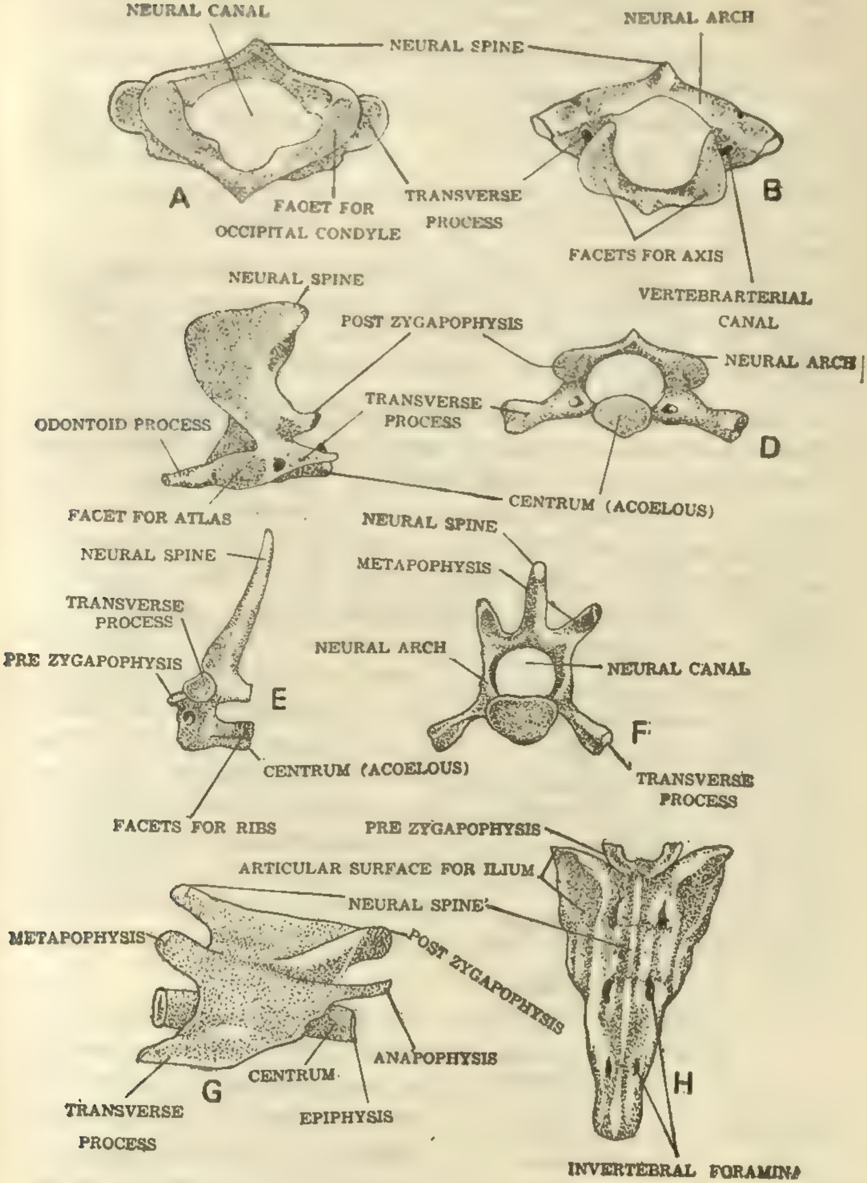


Fig. 46. Different vertebrae of Guineapig, A—Atlas (anterior view), B—Atlas (posterior view), C—Axis (side view), D—Carvical vertebra, E—Thoracic vertebra, F—Lumber vertebra (anterior view), G—Lumber vertebra (side view), H—Sacrum (dorsal view).

there are 12 vertebrae, each bearing laterally a pair of ribs. In the lumber region there are 7 vertebrae. Excepting the first two all the vertebrae in this region bear well-developed transverse processes. In the sacral region the two vertebrae present become enlarged and widened. Against the sides of these lie the iliac bones of the pelvic girdle. The remaining 9 vertebrae which constitute the coccygeal portion are more or less fused together to form a rod-like structure tapering towards the hinder end.

On the mid-ventral region of the thorax lies the sternum or breast-bone consisting of an anterior narrow portion—the manubrium and five segments behind, of which the last one bears an oval plate of cartilage—the xiphoid cartilage.

There are 12 pairs of ribs attached to the sides of the 12 thoracic vertebrae. Of these, 9 pairs articulate ventrally with the sternum and the last 3 pairs have their ventral ends free. The portion of a rib which is articulated with the vertebra is known as vertebral portion and that which is articulated with the sternum as sternal portion. The sternal portions of the ribs are cartilaginous. A rib is attached to the vertebra by two heads : (i) capitulum which articulates with the centrum and (ii) tuberculum which articulates with a facet on the undersurface of the transverse process of the side. The articular facet for the capitulum is, however, provided partly by the anterior edge of the corresponding centrum and partly by the posterior edge of the centrum just in front.

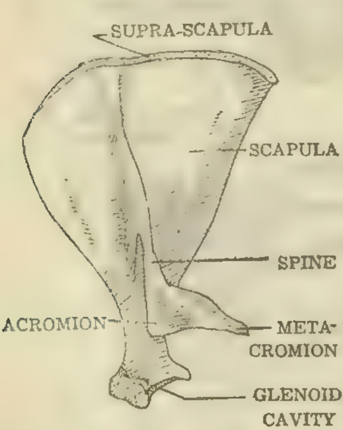


Fig. 47. Shoulder bone (scapula) of the left side of Guineapig.

Appendicular skeleton—The pectoral girdle consists mainly of a shoulder blade on each side lying on the side of the back (Fig. 47). In it the scapula is a triangular plate produced anteriorly into a narrow neck. The broad end is directed backward. The scapula bears dorsally a ridge or spine which becomes free from its body anteriorly to form a process known as *acromion*. This is directed posteriorly into another process—the *meta-cromion*.

At the narrow end of the scapula is a concave facet—the *glenoid cavity* for the articulation of the head of the humerus. Internal to this cavity there is a small knob-like process which represents the *coracoid.* Along the broad end of the scapula lies a narrow cartilaginous strip—the *supra-scapula.* The clavicle is imperfectly developed.

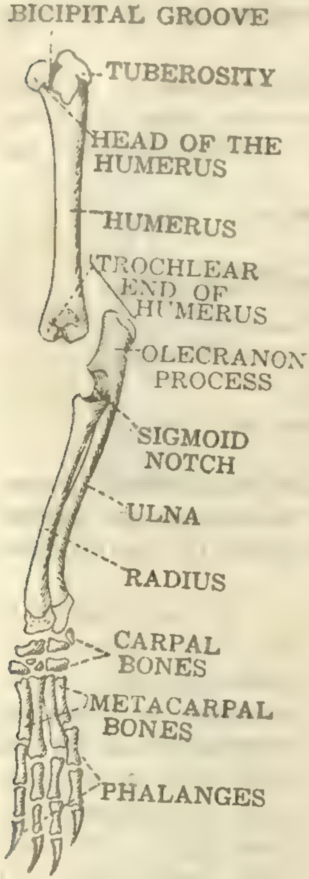


Fig. 48. Forelimb (left) of Guineapig.

In the fore limb, the humerus supporting the upper arm fits by its head into the glenoid cavity (Fig. 48). Beside the head lies a *tuberosity* separated by a groove (*bicipital*). The distal *trochlear* end forms a pulley-like structure. Just above this end there are depressions both in front and behind.

Of the two bones in the forearm, *radius* is slender and smaller than the *ulna.* Proximally the radius lies in front of the unla but distally it becomes broad and lies internal to the ulna. The ulna bears at its proximal end the *sigmoid notch* beyond which extends the *olecranon process.* The trochlear end of humerus fits into the sigmoid notch. In the wrist there are altogether seven *carpal bones* including one pisiform bone on the outer side. There are four *metacarpal bones* corresponding to the four digits. Each digit bears three *phalanges*, the terminal one in each case ending in a horny claw.

The two halves of the pelvic girdle are attached anteriorly to the sides of the sacrum and to each other in the mid-ventral region forming the ventral symphysis.

Each half of the pelvic girdle is known as *innominatum* (Fig. 49) and consists of three bones—*ilium, ischium* and *pubis.* In the region where the three bones meet there is on the outer surface of the os innominatum a concavity—the *acetabulum,* for the articulation of the head of the femur—the thigh bone.

The ilium lies dorsal to the acetabulum and is produced in front. It bears on the outer surface a longitudinal ridge.

The ischium is also dorsal but produced behind. Its posterior margin is thickened.

The pubis extends downward and backward from the acetabulum. It joins with its fellow of the opposite side along the ventral border to form the symphysis (Fig. 50). The hinder part of the symphysis is formed by the union of the posteroventral borders of the ischia of two sides. In each os innominatum the anterior part of ischium is separated from the pubis by the obturator foramen.

Fig. 49. Side view of the innominatum of Guineapig.

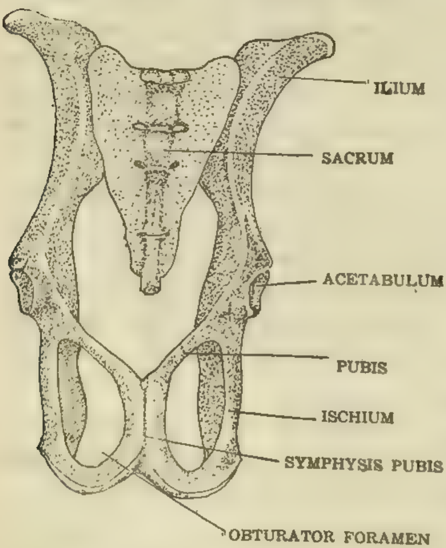


Fig. 50. Ventral view of the pelvic girdle of Guineapig.

In the hind limb, the femur supports the thigh (Fig. 51). At its proximal end it bears a prominent head and the three other prominences—the trochanters. The head lies on the inner side and fits into the acetabulum. The prominent great trochanter is on the outer side and is separated from the head by a groove. Below the head is the lesser trochanter. The third trochanter is placed below the great trochanter. Distally the femur bears two condyles separated by a notch, for articulation with the bones of the leg.

Of the two bones in the leg, tibia lies on the inner or preaxial side and fibula on the outer or post-axial side of the limb. The tibia is stouter and its proximal end bears two oval surfaces. Just below the proximal end the tibia bears on its front surface a ridge—the cnemial crest. The fibula is slender and is distinct from the tibia.

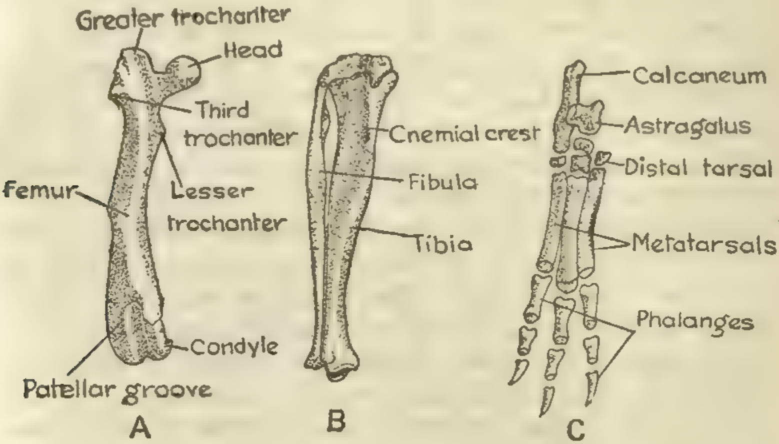


Fig. 51. Hind-limb of Guineapig.

A small knee-cap or patella lies on the front side of the knee-joint—between the thigh and leg. It is a sesamoid bone formed as a result of ossification embedded in the extensor tendon over the knee.

In the region of the ankle there are six tarsal bones. The two tarsal bones lying proximally are large, and are known as (i) astragalus—on the inner side, articulating by a pulley with the tibia, and (ii) calcaneum—on the outer side produced backward into a large process or heel. The calcaneum however does not articulate with the fibula. The other tarsal bones lying distally are small in size. The metatarsal bones are three in number corresponding to the three digits or toes. Each digit bears three phalanges. The terminal phalanges end in horny claws.

Alimentary System (Fig. 52)

The alimentary canal begins at the mouth bounded by the lips of which the upper one is incised in the middle. The mouth leads into the mouth cavity the roof of which is called the palate. The anterior portion of the palate is marked by transverse ridges and is known as the hard palate whereas the smooth fleshy posterior

portion is known as the soft palate. On the floor of the mouth cavity is attached the muscular tongue of which the tip of the anterior end is free. The tongue bears on its surface several papillae which subserve the sense of taste.

The guineapigs have two sets of teeth—the milk set and the permanent set. The milk teeth are replaced very early in life by the permanent set of teeth. Teeth are present both on the upper and lower jaws. The teeth are not alike and do not from continuous sets. They are placed in sockets in the jaws. The upper jaw bears on each side, one curved chisel-shaped incisor in front with a cutting edge and at the side four cheek teeth or grinding teeth with transverse ridges (lophodont) on the grinding surface. Of these four teeth, the first one known as premolar is preceded by one in the milk set, whereas the last three, known as molars, are not. The lower jaw has on each side similar teeth as in the upper jaw. The guineapig is thus heterodont possessing different types of teeth. On each side in each jaw of the guineapig there is a wide toothless gap known as **diastema** between the incisor and the premolar. In many mammals there is another type of teeth, known as the canine, which are situated in the spaces between incisors and premolars.

The number of the different kinds of teeth possessed by an animal can be expressed by a *dental formula* which represents the teeth (denoted by initial letter) present in each side. The dental formula in guineapig is i 1/1. c 0/0 pm. 1/1 m. 3/3, in which the upper (first) figures indicate the numbers of different teeth in each side of the upper jaw and the lower (second) figures those in each side of the lower jaw.

Opening into each side of the mouth cavity are the ducts of the four salivary glands of that side. These glands are—**parotid** lying between the external ear and lower jaw, and **infra-orbital, sub-lingual** and **sub-maxillary** below the eye, tongue and upper jaw respectively. The *saliva* secreted by the glands moistens the food, aids in swallowing and contains an enzyme known as ptyalin which converts starches into sugars.

Beyond and behind the margin of the soft palate the mouth cavity leads into the pharynx. The pharynx leads behind into the gullet dorsally and glottis ventrally.

The pharynx consists of an upper nasal division and a lower buccal division. The nasal division receives anteriorly the posterior nasal chamber formed by the union of two posterior nares, and

at the sides the openings of the eustachian tubes. The buccal division is in continuation with the buccal cavity proper; on the floor of this buccal division is a slit-like opening—the glottis. A thin flap of cartilage known as epiglottis arises from the anterior border of glottis which it overhangs. Dorsal to the glottis is the gullet or the opening of the oesophagus. In the pharynx, the passages for food from the buccal cavity to the oesophagus and for air from the posterior nasal chamber to the glottis cross each other. During the act of swallowing the posterior nasal opening becomes closed by the soft palate whereas the epiglottis protects the opening of the wind pipe, so that the food passes straight into the oesophagus. During breathing, glottis comes in close apposition with the posterior nasal chamber and a continuous passage for air is thus established. Swallowing and breathing cannot be performed at the same time; during one of these processes the other remains suspended. The oesophagus is long and narrow and runs backward through the neck region along the dorsal side of the trachea. It then passes through the thoracic cavity and enters the abdominal cavity through an aperture in the diaphragm (Fig. 52) opening at once into the stomach. The stomach is a wide sac and consists of cardiac and pyloric portions -the two being separated by a slight constriction. At the cardiac end enters the oesophagus; from the plyoric end arises the **small intestine**. The internal lining of the stomach is raised into numerous longitudinal folds. At the junction of the stomach with the small intestine there is a constriction known as the pyloric constriction which indicates the presence of a circular ring-like valve inside.

The small intestine is narrow and greatly coiled. It is divided into two portions. The first portion known as the **duodenum** forms a U-shaped loop. The latter portion of the small intestine known as the **ileum** is very long and is much coiled. The internal lining of the intestine is thrown into numerous minute projections called **villi** by which its absorptive surface is greatly increased. The small intestine is continued behind as the **large intestine.** This is a wide tube, the anterior portion of which -the colon, has its walls sacculated and is continued into the narrow smooth-walled posterior portion—the **rectum.** At the junction of the small intestine with the large intestine is a wide blind tube—the **caecum** which is of considerable length and is marked by spiral constrictions indicating the presence in its interior of a narrow spiral valve. The large intestine terminates posteriorly at the anus. The alimentary canal is throughout supported by folds of mesentery. From the stomach

extends a special fold of peritoneum known as the great omentum which is usually loaded with a large quantity of fat.

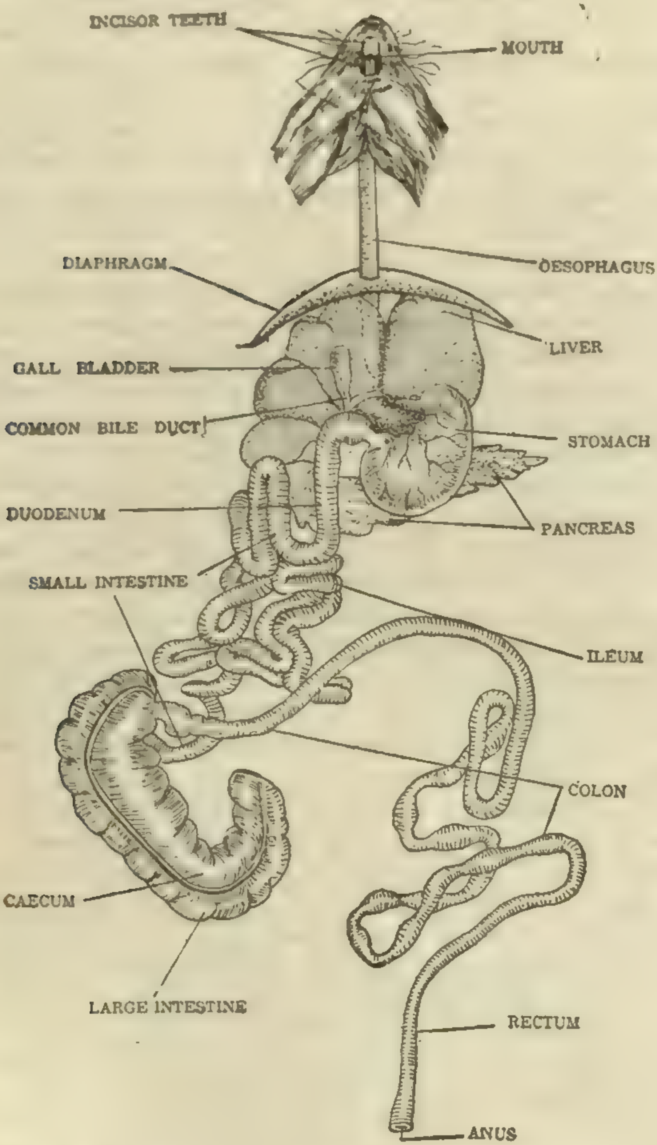


Fig. 52. Diagram of the alimentary system of Guineapig.

Among the digestive glands, the liver is a large gland consisting of five lobes, placed against the posterior surface of the diaphragm.

The **gall bladder** is a thin-walled sac and lies in a depression on the posterior surface of the liver between the 3rd and 4th lobes from the right side. The common bile duct, formed by the union of the cystic duct from the gall bladder and the hepatic ducts from the various parts of the liver, runs to open into the portion of the duodenum near the pyloric end of the stomach.

Pancreas is a diffused gland in the folds of the mesentery. Passing across the loop of the duodenum its single duct opens into the distal limb of the loop.

Ductless Glands

Within the body of the animal there are certain glands which do not convey their secretions through ducts. These are known as ductless glands or endocrine glands and they pour secretions into the blood. The following ductless glands need mention:

(1) Spleen—it is a reddish structure placed on the dorsal side of the stomach.
(2) Thyroid—this consists of two lobes one on each side of the thyroid cartilage of the larynx.
(3) Thymus—this is usually present in the early stage as a mass above the heart. It atrophies in the adult stage.
(4) Supra-renal attached to the front end of each kidney as a yellowish white body.

Other ductless glands, viz., pituitary and pineal bodies are mentioned in connection with the brain.

Vascular System

The heart (Fig. 53) is situated in the cavity of the thorax a little to the left of the middle line and lies between the two pleural sacs enclosing the lungs. The space between the two pleural sacs is known as the **mediastinum.** The pericardial membrane enclosing the heart consists of two layers—(i) a parietal layer forming the outer wall of the pericardial cavity and (ii) a visceral layer immediately investing the heart. The heart consists of four chambers—the right and left auricles and the right and left ventricles. The sinus venosus is absent. The right and left sides of the heart are completely separated off one another by inter-auricular and inter-ventricular partitions (Fig. 53). On the inter-auricular septum, there is an oval area where the partition is thinner than elsewhere; this is known as **fossa ovalis.** It marks the position of an aperture—the **foramen ovale**—in the foetus. The crescentic anterior rim of this is known as **annulus ovalis.** The right auricle receives the venous blood from the anterior region of the body by an anterior

vena cava and from the posterior region by a posterior vena cava. Projecting anteriorly from the right auricle is a blind pouch—the right auricular appendix. The right ventricle is thick-walled and muscular. The cavity of the right auricle communicates with that of the right ventricle by the wide auriculo-ventricular opening guarded by a valve—the tricuspid, composed of three lobes or

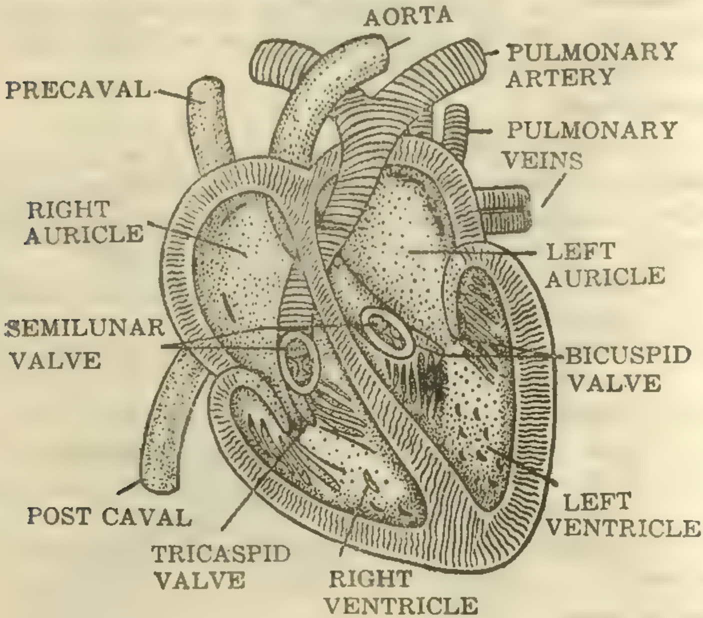


Fig. 53. Diagram showing the heart of Guineapig.

cusps, so arranged and attached that while they flap back against the walls of the ventricle to allow the passage of blood from the auricle to the ventricle, they meet together across the aperture so as to close the passage when the ventricle contracts. The free ends of the cusps are connected with the muscular columns **(columnae carneae)** on the walls of the ventricle by means of **tendinous** threads—the **chordae tendineae.** The right ventricle gives off in front the pulmonary artery, which later divides into two branches, each going to a lung. The opening leading from the right ventricle to the pulmonary artery is guarded by three semilunar valves. The left auricle is also provided with an auricular appendix. Into it, on its dorsal aspect, open the pulmonary veins from the lungs. The left ventricle is a thick-walled chamber and is partly surrounded by the right ventricle. The left auriculo-ventricular opening which commu-

nicates the cavity of the left auricle with that of the left ventricle, is guarded by a mitral or bicuspid valve consisting of two lobes or cusps. The columnae carneae are more strongly developed on the walls of the left ventricle. At the anterior end of the left ventricle is given off the aorta, the entrance to which is guarded by three semi-lunar valves similar to those at the entrance to the pulmonary artery.

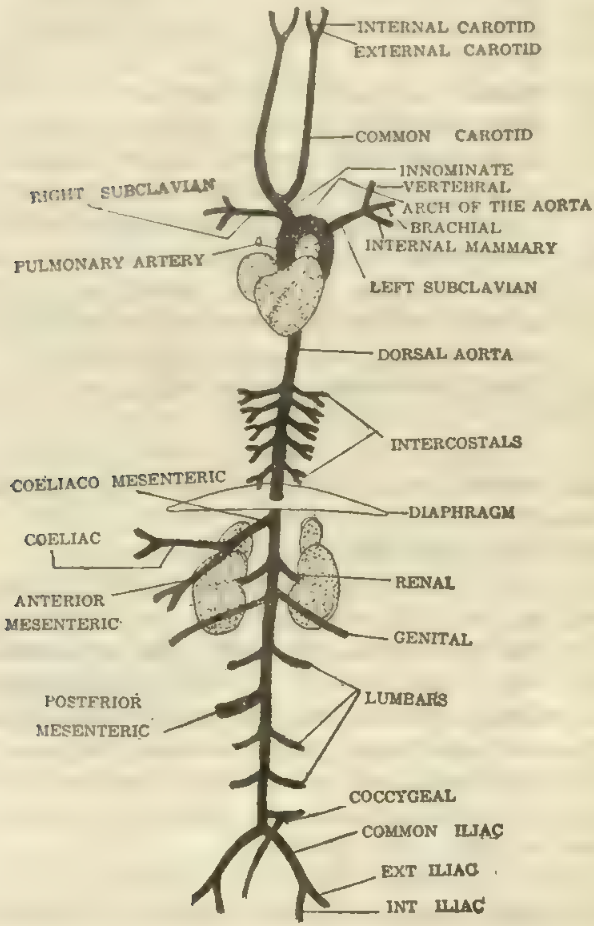


Fig. 54. Diagram showing the arterial system of Guineapig.

The **aorta** which arises from the left ventricle runs forward, then curves to the left and runs backward in the median line as dorsal aorta through the thorax and abdomen, along the ventral

side of the vertebral column (Figs. 54 & 56). From the thorax the dorsal aorta passes into the abdomen through an aperture in the diaphragm.

The following are the main arteries given off by the aorta:

I From the arch of the aorta:

(1) innominate, which divides into

(a) right subclavian artery—this sends out (i) a vertebral artery supplying blood to the region of vertebral column, (ii) an internal mammary (anterior epigastric) artery conveying blood to the inner side of the ventral thoracic wall and is itself continued as the brachial artery supplying the parts of the fore limb;

(b) & (c) right and common carotid arteries. Each of these arteries runs forward along the side of the trachea in the neck region and divides near the level of the larynx into an external and an internal carotid artery. The external carotid arteries supply blood to the parts of the face whereas the internal carotid arteries supply blood mainly to the brain;

(2) left subclavian—this has similar branches as in the right one.

II From the thoracic portion of the aorta are given off a series of small arteries—the intercostal arteries—supplying blood to the dorsal thoracic wall. Arteries are also given out from this portion to supply the region of the oesophagus.

III The aorta then pierces the diaphragm and in the abdominal region gives out the following arteries:

(1) a coeliaco-mesenteric artery—this arises as a single trunk but soon divides into (i) a coeliac artery sending out branches to stomach, liver and spleen and (ii) an anterior mesenteric artery supplying branches to the pancreas and portions of small intestine and also to caecum and colon;

(2) a pair of renal arteries to the kidneys, of which the right one is slightly anteriorly placed;

(3) a pair of genital arteries to the reproductive organs;

(4) a posterior mesenteric artery—giving out branches to the portions of large intestine.

The aorta in the adbominal region also gives out a few small lumbar arteries to supply blood to the muscles of the dorsal side in the abdominal region.

Near the posterior region of the abdominal cavity, the aorta divides into two iliac arteries. Slightly anterior to the region of

the origin of the iliac arteries, the aorta gives out a small artery to the region of the coccyx forming what is known as the coccygeal artery. Each iliac artery divides and forms (i) an external iliac artery continued into the hind limb as femoral artery and (ii) an internal iliac artery supplying the ventral abdominal wall, bladder, uterus in the female, and the adjacent parts.

The coronary artery supplying the muscles of the heart is given off from near the base of the aorta. The corresponding vein opens into the terminal portion of the anterior vena cava.

There are two larger veins (Figs. 55 & 56)—the anterior and posterior venae cavae opening into the right auricle. The pulmonary veins from the lungs open into the left auricle. The anterior vena cava which brings back blood from the anterior region of the body is formed by the union of two innominate veins, one from each side. Each innominate vein is formed by the union of the following smaller veins;

(i) external jugular vein returning blood from the side of the head and face;
(ii) internal jugular vein returning blood from the brain;
(iii) sub-clavian vein returning blood from the fore limb of the side;
(iv) anterior intercostal vein returning blood from the anterior thoracic wall; and
(v) internal mammary vein returning blood from the inner side of the ventral wall of the thorax.

The anterior vena cava before opening into the right auricle receives the azygos vein, returning blood from the dorsal region of the thoracic wall.

The posterior vena cava, which returns blood from the hinder region of the body, is formed near the posterior end of the abdominal cavity, by the union of two iliac veins, and runs forward along the side of the aorta. An external iliac vein from the hind limb and an internal iliac vein from the parts of the pelvic region join to form the iliac vein of the side. The posterior vena cava, in its course towards the heart, receives a coccygeal vein, a few small lumber veins from the muscles of the dorsal body wall in this abdominal region, a pair of genital veins from the reproductive organs, and a pair of renal veins from the kidneys. The posterior vena cava then passes forward through the liver and as it emerges out of the liver anteriorly, it receives a pair of hepatic veins from the liver and a pair of small veins from the diaphragm.

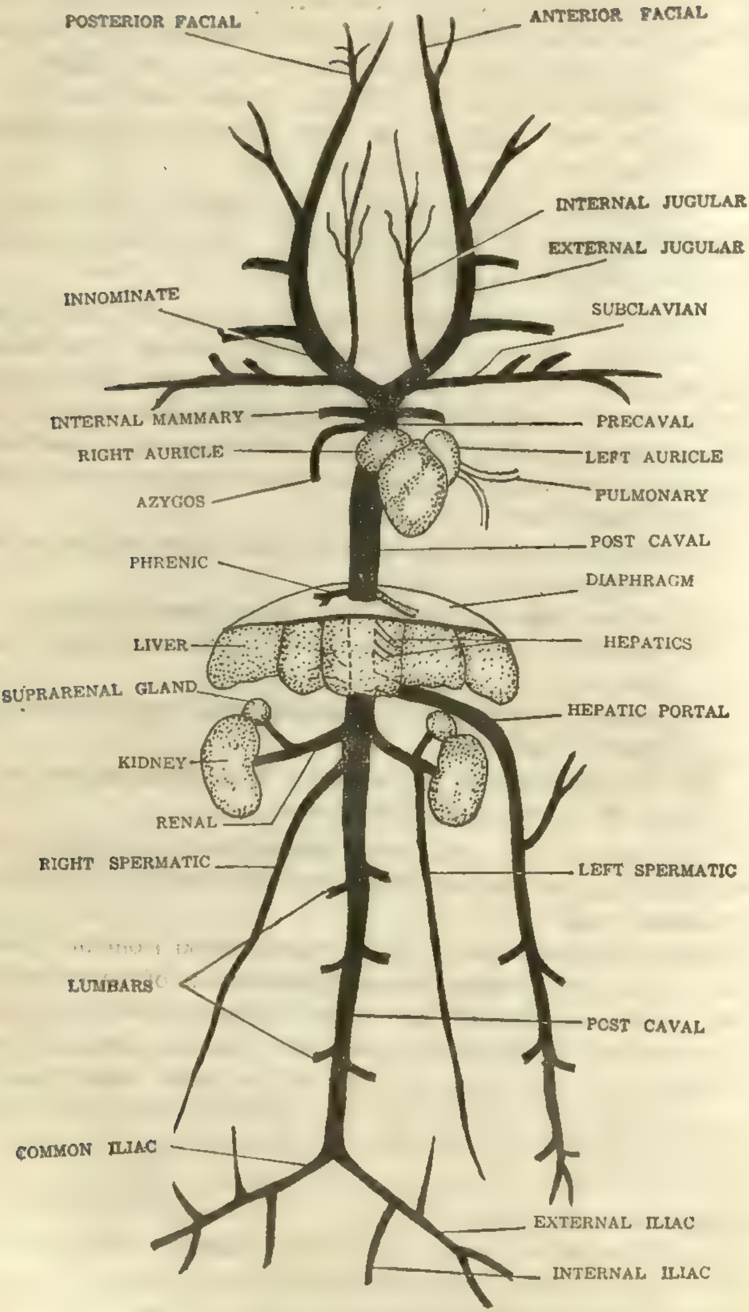


Fig. 55. Diagram showing the venous system of Guineapig.

Blood from the various parts of the alimentary canal and associated glands is returned through the hepatic portal vein which

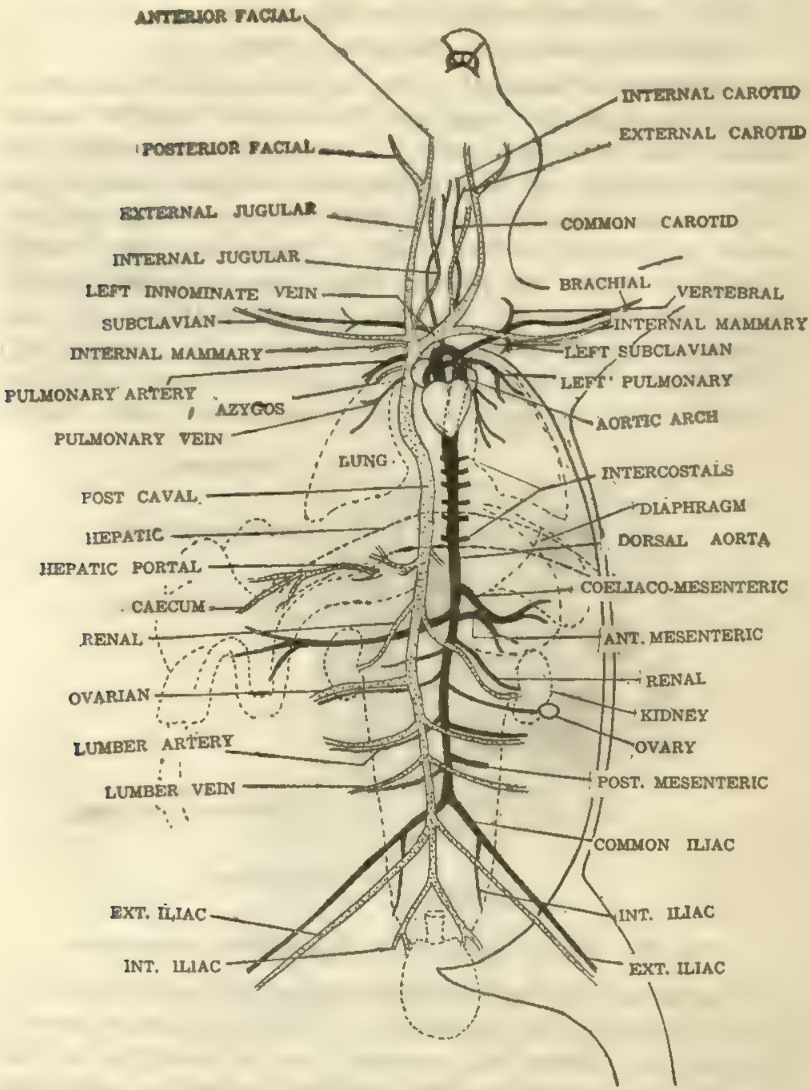


Fig. 56. Vascular system of Guineapig.

pours its contents into the liver. The branches which unite to form the hepatic portal vein are:

(i) a lieno-gastric returning blood from spleen and stomach;

(ii) a duodenal returning blood from the duodenum;
(iii) an anterior mesenteric from parts of small intestine, colon and caecum; and
(iv) a posterior mesenteric from the rectum.

There is no trace of a renal portal system.

Circulation of blood—(Fig. 56) In the course of circulation through the heart, the oxygenated blood which the left auricle receives from the lungs, passes into the left ventricle and then through the aorta and its branches to the different parts of the body. In the tissues of the body, blood becomes deoxygenated and impure by receiving carbon dioxide. This impure blood returns through the anterior and posterior venae cavae to the right auricle. From here it passes into the right ventricle and then it is sent through the pulmonary arteries to the lungs. The blood is oxygenated and gets rid of its carbon dioxide in the lungs and is then returned to the left auricle through the pulmonary veins. During

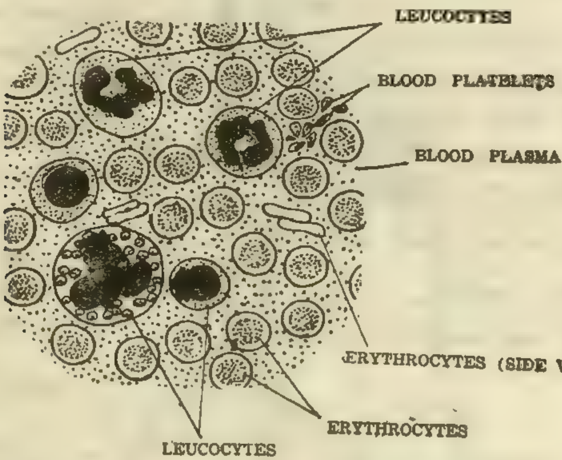


Fig. 57. Blood of Guineapig showing different components.

the contraction of the heart the contraction of the auricles is followed by the contraction of the ventricles. The two auricles contract simultaneously driving their contents into the ventricles, so that when the auricles contract, the ventricles expand by being filled with blood from the auricles. The ventricles then contract simultaneously driving their contents into the arterial trunks. During ventricular contraction, auricles relax after contraction and expand by being refilled with blood from the veins. The rhythmic contractions of the heart continue as long as the animal lives.

The blood (Fig. 57) is composed of a fluid part, known as *blood plasma*, in which are suspended numerous cells known as *corpuscles*. These are of two types—red blood corpuscles or *erythrocytes* and white blood corpuscles or *leucocytes*. The red blood corpuscles are rounded, biconcave and non-nucleated structures. These cells contain haemoglobin, an iron containing red pigment. The white blood corpuscles are nucleated, colourless and fewer than red blood cells. Besides the red and white blood corpuscles, several smaller cells are found in blood. These are known as *blood platelets* or *thrombocytes*. These help in coagulation of blood in case of an injury.

Respiratory System

This consists of the larynx or the organ of voice, the trachea and the two lungs (Fig. 58). The glottis in the buccal cavity leads

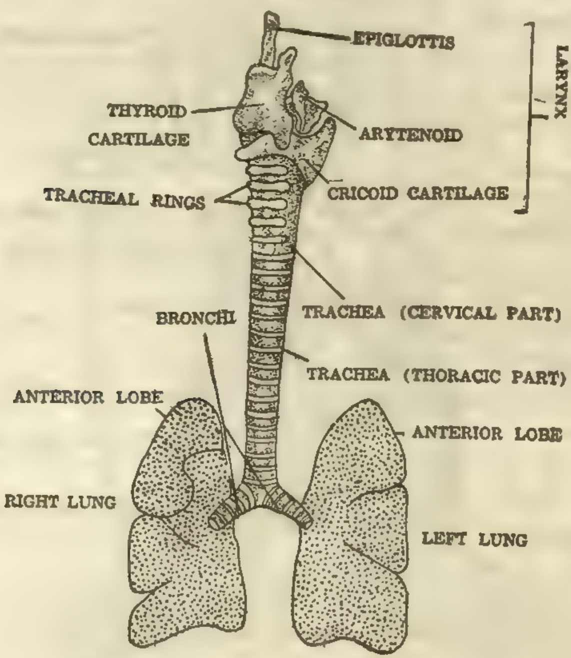


Fig. 58. Respiratory organs of Guineapig.

to the larynx. It is a wide chamber with walls supported by cartilage which are held together by muscles and membranes. There is a large **thyroid cartilage** forming the ventral and lateral walls. Within the thyroid is situated a ring-like **cricoid** cartilage. Anterior

to the cricoid, there is a pair of small **arytenoid** cartilages, one on each side of the middle line. At the apex of each arytenoid is placed

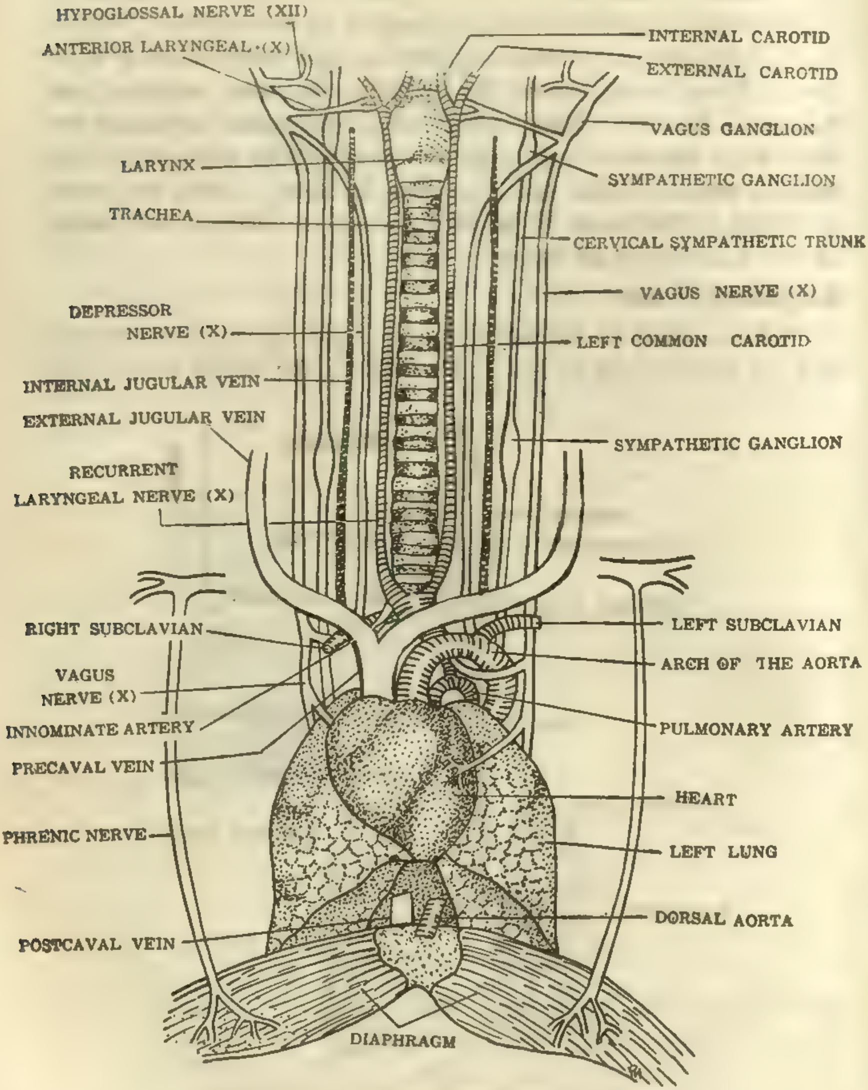


Fig. 59. Diagram showing the nerves and blood vessels in the neck of Guineapig.

a small nodule of cartilage known as the **cartilage of Santorini.** Inside the larynx, membranous flaps extend from the thyroid, towards the dorsal region, which are known as **vocal cords.** As the air

rushes out of the larynx, these cords are set into vibrations which produce the sound or voice. The laryngeal chamber can be narrowed down by muscular activity which causes changes in the sound produced.

The larynx is continued behind as trachea or wind pipe, a long tube, the wall of which is supported by a series of cartilaginous rings which are incomplete dorsally. It lies in the neck region and on entering the thoracic cavity divides into two tubes—the bronchi also supported by incomplete cartilaginous rings. Each bronchus passes into the root of the corresponding lung. There are two lungs one on each side. Each projects into a cavity lined by the pleural membranes. The lungs are pinkish spongy bodies with the apex directed forward. The bronchus and the pulmonary artery and vein pass into the middle of the lung through its root.

The bronchus on entering the lung divides and subdivides, forming smaller branches—the bronchioles. Each bronchiole terminates in a thin-walled sac known as **alveolus**. The walls of the alveoli are richly supplied with the net work of capillaries which is connected with the pulmonary artery on one side and the pulmonary vein at the other.

During respiratory movements, the muscles in the chest wall contract and the diaphragm is also lowered. This causes an expansion of the chest cavity with a consequent fall of pressure and air rushes into the lungs through the wind pipe. This is **inspiration.** In toad air is forced into the lungs but here there is a sort of suction action by which air enters the lung. In the course of expiration, muscles of the chest wall and the diaphragm relax assuming normal position. By this, a pressure is exerted on the air drawn during inspiration within the lungs, and this pressure forces the air out. There is also an elastic recoiling of the lungs themselves which aids expiration.

Nervous System

The nervous system of guineapig (Fig. 59) is divided into three main systems—(1) central nervous system, (2) peripheral nervous system and (3) autonomic nervous system.

Central nervous system—The central nervous system consists of brain and spinal cord. The brain and the spinal cord remain covered by three membranes or meninges. These are known as (1) duramater, (2) arachnoid mater, (3) piamater.

Brain—The brain consists of three parts; fore-brain or procencephalon, mid-brain or mesencephalon and hind-brain or rhombencephalon. The fore brain is subdivided into two parts and the hind brain is also subdivided into two parts.

- Brain
  - Fore brain or Procencephalon
    - Telencephalon
    - Diancephalon or Thalamencephalon
  - Mid brain or Mesencephalon
  - Hind brain or Rhombencephalon
    - Myelincephalon
    - Metacephalon

In the fore brain, the two cerebral hemispheres are long and narrow in front (Figs. 60 and 61). These extend behind to cover the thalamencephalon and the optic lobes. The surface of the hemispheres is marked out into convolution by certain depressions or **sulci.** A slight depression known as the Sylvian fissure at the side of each hemisphere separates off a temporal lobe from the rest of the hemisphere which consists of a frontal lobe anteriorly, a parietal lobe in the middle and an occipital lobe behind. At the anterior end of each cerebral hemisphere is situated the large club-shaped olfactory lobe.

Connecting the two cerebral hemispheres is a transverse nerve commissure known as **corpus callosum**—which lies above the level of the lateral ventricles. Underlying the lateral ventricles is another transverse band of nerve tissue—the **corpus striatum.**

The optic thalami forming the lateral portions of the thalamencephalon (diencephalon) are large. A rounded elevation near the anterior end of the external surface of each thalamus is the **corpus geniculatum**. From the roof of the diencephalon arises the pineal body. The floor of the diencephalon is produced into a median infundibulum to the end of which the glandular pituitary body is attached. Behind the infundibulum is another rounded elevation—the **corpus mammillare.**

In the mid-brain the optic lobes are dorsally placed and four in number **(corpora quadrigemina)**, with the prominent crura cerebri occupying the ventral region.

In the hind-brain cerebellum is very large. It consists of a central lobe and two lateral lobes. Each lateral lobe bears an irregular prominence—the flocculus. A band of transverse fibres—the **pons varoli**, connects the lateral lobes of the cerebellum ventrally.

The hindermost part of the brain is medulla oblongata which is continuous with the spinal cord behind. The interior of the

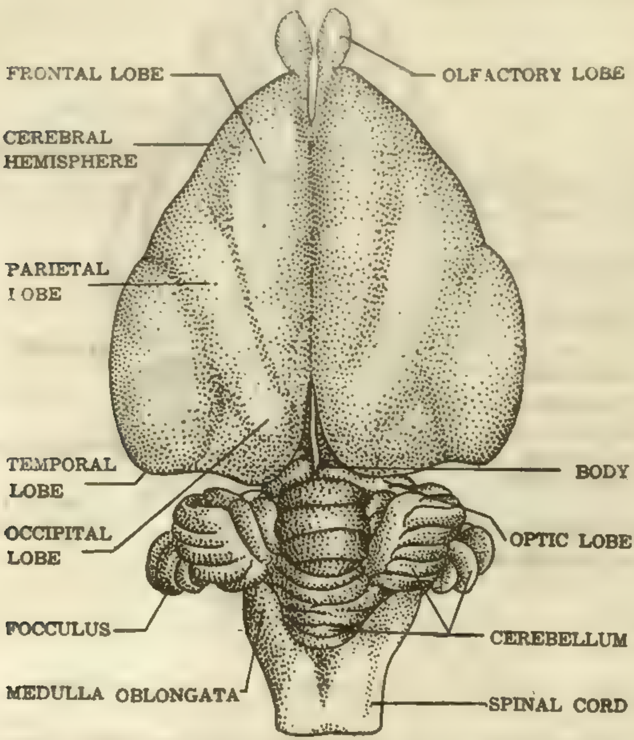


Fig. 60. The brain of Guineapig as seen from above.

brain is hollowed by four cavities. These cavities within the brain is called the ventricles and these ventricles are filled with cerebrospinal fluid. The fourth ventricle is continued downwards as the central canal or neuroceol of the spinal cord. The neurocord is also filled with cerebrospinal fiuid.

The brain and the spinal cord together form the central nervous system whereas their nerves, ganglia and the sense organs

with which these nerves are connected together constitute the peripheral nervous system.

According to their position peripheral nerves are divided into two groups. (1) Cranial nerves, (2) Spinal nerves.

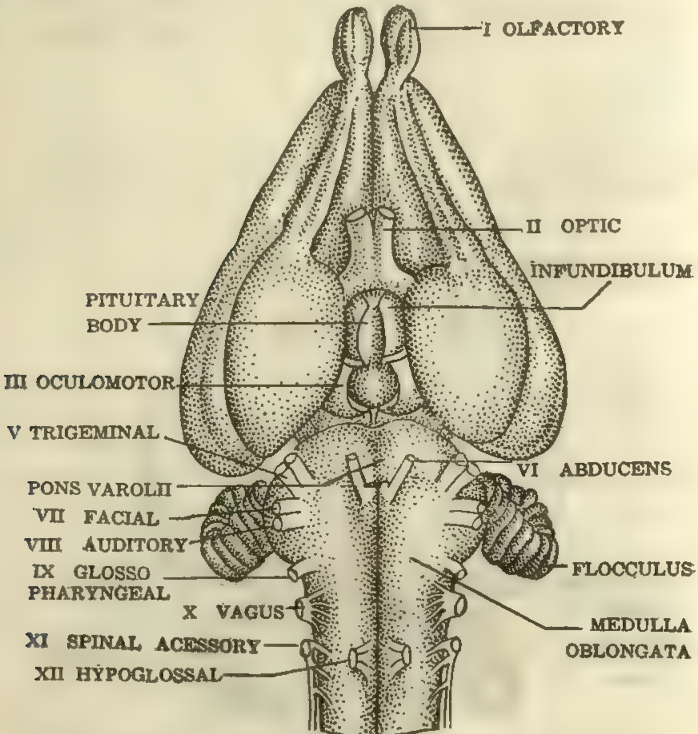


Fig. 61. The brain of Guineapig as seen from below.

According to their functions they may be divided into three groups.

(1) Afferent or sensory i.e., those nerves which carry impulses from outside towards the brain.

(2) Efferent or motor i.e., those nerves which convey impulses from the axis to other portion outside.

(3) Mixed nerves—These are mixed type of both efferent and afferent nerves.

Cranial nerves—The cranial nerves on each side are twelve in number.

Name of the carinal nerves	*Nature*	*Orogin*	*Branches and distribution*
I. Olfactory	Sensory	Procencephalon, ventral surface.	Olfactory body.
II. Optic	"	Diencephalon, Ventral surface, optic thalamus.	Retina of the eye.
III. Oculomotor	Motor	Mecencephalon, ventral surface.	Muscles of the eye ball.
IV. Trochlear	"	Mesencephalon, from the dorsal surface between the optic lobe and cerebelum.	Muscles of the eye ball.
V. Trigeminal	Motor	Myelencephalon, from the sides.	(i) Opthalmic branch, supplying the eyelids and the skin around the snout. (ii) Maxillary branch, supplying upper jaw, upper lip & muscles of adjacent parts. (iii) Mandibular branch, supplying muscles of the floor of the mouth, tongue & lower lip.
VI. Abducen	"	Myelencephalon, ventral surface.	Muscles of the eye ball.
VII. Facial	Mixed	Myelencephalon, close to the origin of V.	(i) Palatine branch supplying the palate or the roof of the mouth. (ii) Hyomandibular branch supplying the skin and muscles of the lower jaw.
VIII. Auditory	Sensory	Myelencephalon, ventral surface.	Supplying auditory capsule, internal ear, cochlea and vestibule.
IX. Glossopharyngeal	Mixed	Myelencephalon, by roots common with X.	Supplies the floor of mouth and tongue.
X. Vagus	Mixed	Myelencephalon, from the sides.	(i) A branch to the larynx. (ii) A branch to the recurrent laryngeal nerve to larynx. (iii) A branch which subdivides, the depressor nerve supplying the heart and continuous to the stomach, viscera and liver.
XI. Spinal accessory	Mixed	Myelencephalon,	Supplying the muscle of the pharynx.
XII. Hypoglossal	Motor	"	Supplying the muscle of the tongue.

Spinal nerves

Spinal nerves, i.e., the nerves given out from the spinal cord pass out on each side through the intervertebral foramina and are distributed over parts of the body. Each nerve arises from the spinal cord by two roots—a dorsal and a ventral. In this dorsal root lies the dorsal root ganglion.

The dorsal root consists of sensory fibre and the ventral root of motor fibres so that each spinal nerve is a mixed nerve.

Autonomic nervous system—Autonomic system controls the activity of viscra. Its actions are generally unconscious and independent of will.

The **sympathetic nervous system** consists of two ganglionated nerves one on each side of the certebral column. In the region of the neck there is on each side an anterior and a posterior cervical ganglion. In the region of the thorax, nerve fibres are given off from the ganglia of the sympathetic cord, which form plexuses over the heart and lungs. In the abdomen, similar nerves are given out from the sympathetic ganglia which form plexuses over the aorta and its branches and also over the region of the intestine.

Excretory System

In the abdominal cavity, there is a pair of **kidneys** one on each side of the median line of the dorsal body wall. These are bean-shaped structures, with the convex surface away from the median line. The **ureter** begins from the inner concave region of each kidney and passes backward and opens along the dorsal side into the **urinary bladder.** The bladder is a median sac lying ventrally in the hindermost region of the abdominal cavity. The neck of the bladder is produced into a narrow canal known as the **urethra.** In the male, urethra traverses the penis and opens to the exterior at its tip. From the neck of the urinary bladder in male there is on the dorsal side an outgrowth known as **uterus masculinus.** In the female the urethra is short and opens to the exterior behind the clitoris.

Reproductive System

In males, there is a pair of testes lying within the cavity inside the body. In a mature adult animal, during the breeding period, these come out of the cavity and lie within the scrotal sac. To each testis is applied a mass known as epididymis (Fig. 62). This consists of a much convoluted tubule arising from the testis. From the epididymis comes out the vas deferens which crosses the ureter of

the side ventrally and opens into the neck of the urinary bladder along the dorsal side. An outgrowth known as uterus masculinus arises from the dorsal side of the neck of the urinary bladder and is produced anteriorly into a pair of elongated portions. A gland known as prostate surrounds the urethra at its base. The penis which is traversed by the urethra is an elongated organ used in copulation. Three longitudinal strands of highly vascular spongy tissue constitute the penis. The strand on the dorsal side connecting it with the perinaeum is known as the **corpus spongiosum**; the other two strands—**corpora cavernosa** are antero-lateral in position and continuous with the abdomen. At the tip of the penis the corpus spongiosum enlarges to form the **glans penis.**

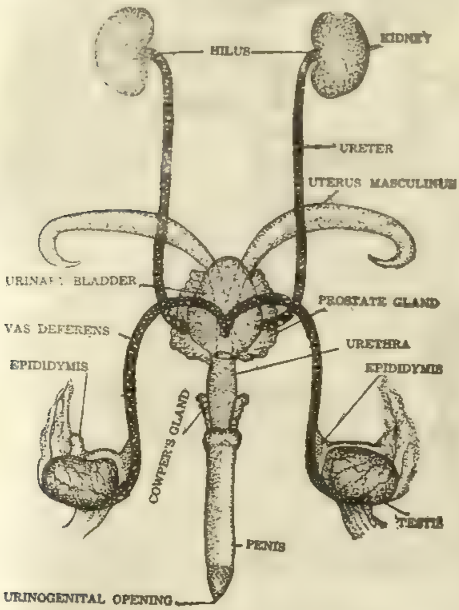


Fig. 62. Urinogenital organs of male Guineapig.

In females, there is within the abdominal cavity on each side of the median line a small ovary attached to the dorsal body wall just behind the kidney. From near each ovary begins an oviduct with a funnel-shaped mouth. Its anterior portion—known as **fallopian tube** is slightly convoluted (Fig. 63). The middle portion of the oviduct is wide and thick-walled and is known as the uterus. Within this portion the fertilized ovum becomes attached and develops as the **foetus.** Posteriorly behind the uterus the two oviducts unite and form a common passage known as **vagina**. The vagina is continued behind into a wide space known as **vestibule** which opens to the exterior through the vulva. On the sides of the vulva are situated two prominent folds known as **labia majora.**

The guineapig is viviparous. The ova develop within certain cavities—the graffian follicles, developed on the inner side of the surface of the ovary. By a process known as **ovulation,** the mature ova are shed by the bursting of the wall of the ovary and pass

directly into the fallopian tube. The region from where an ovum comes out of the ovary is marked by a scar. In the process of copulation seminal fluid containing mature sperms passes into the vagina. The sperms travel up through the oviduct and usually in the region of the fallopian tube one of these fertilizes an ovum.

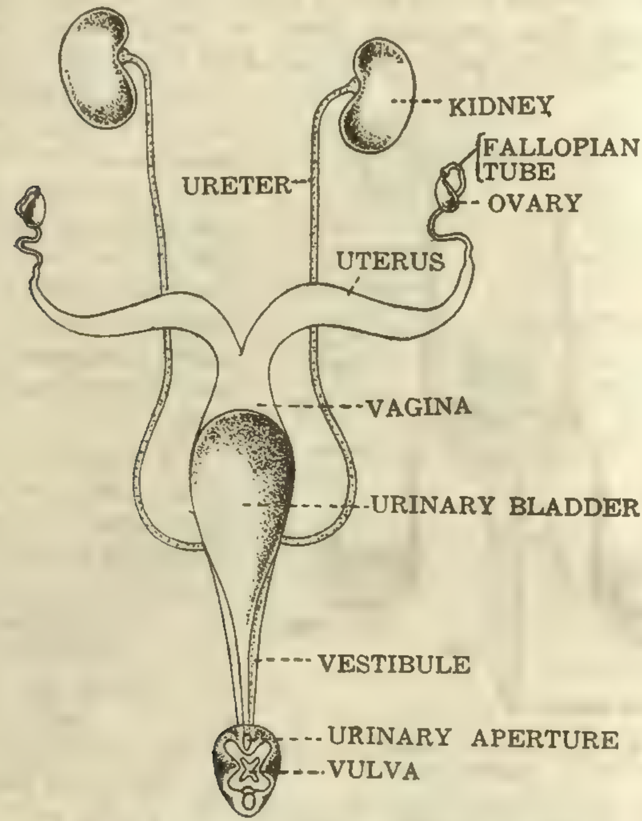


Fig. 63. Urinogenital organs of female Guineapig.

The fertilized ovum then comes down the tube and reaches the uterus to the wall of which it becomes attached through a structure known as **placenta** and undergoes further development to form the foetus **(intra-uterine embryo)**. A structure known as **corpus luteum** is formed in the region of the ovary wherefrom ovulation takes place. In case of conception, whereby the fertilized ovum gets attached to the uterine wall to undergo further development, the corpus luteum continues and functions as a hormone-secreting structure ; otherwise it degenerates. The formation of corpus luteum during the period of conception causes further ovulation to remain suspended.

The period from the time of fertilization till the birth of the young one is known as the period of gestation. During this period which is about 10 weeks in these animals, the embryo grows within the uterus drawing nourishment from the body of the mother through the placenta. Usually 4 to 6 young ones are born in a litter. At the time of birth the development in the young ones is far advanced and these are capable of eating corn in 2 or 3 days after birth. It takes about a year for them to grow to the adult size and attain maturity. These animals possess a life span ranging from 5 to 10 years.

Sense organs

The principal sense organs are the nasal chambers, ears and eyes, serving as receptors for the sensation of smell, hearing and vision respectively. Besides these, the skin serves as an organ for the sensation of touch due to the presence of touch cells in it and the tongue with the help of the taste buds on it serves as an organ for the reception of the sense of taste.

Ear—The ear or the organ of hearing consists of three parts (Fig. 64). These are the inner ear, the middle ear and the external ear. To the external ear is added a broad expanded ear lobe or **pinna.**

The inner ear consists of a **membranous labyrinth** which is fitted inside the **bony labyrinth.** The space inside the membranous labyrinth is filled with a fluid known as **endolymph,** whereas the fluid which fills the space between the membranous labyrinth and bony labyrinth is known as **perilymph.** The membranous labyrinth consists of three chambers—a ventral **sacculus** and a dorsal **utriculus.** Connected with sacculus there is a spirally coiled structure known as **cochlea.** Inside this cochlea there is a sheet of sensory cells known as the **organ of Corti** which is the essential part in the organ of hearing. Connected with the utriculus, are three semi-circular canals situated in three planes. At the end of each of these canals there is a swelling known as an **ampulla.** There are sensory hairs inside, which being stimulated by the waves of movement in the lymph, give the animal the sense of position or of equilibrium.

The middle ear to **tympanum** is a cavity filled with air. This cavity communicates through the **eustachian tube** with the cavity of the pharynx. Inside the middle ear there is a chain of three bony ossicles—(i) **malleus,** (ii) **incus** and (iii) **stapes.** The stapes is placed against the aperture **(fenestra ovalis)** which communicates the middle ear with the inner ear. Malleus is placed against the

tympanic membrane which separates the middle ear from the external ear.

Sound waves entering the external ear cause the tympanic membrane to vibrate. These vibrations are transmitted through the bony ossicles to the fluid filling the inner ear and thence to the sensory cells in the cochlea. As the sensory cells are in communication with the branches of the auditory nerve, the animal receives the sensation of hearing.

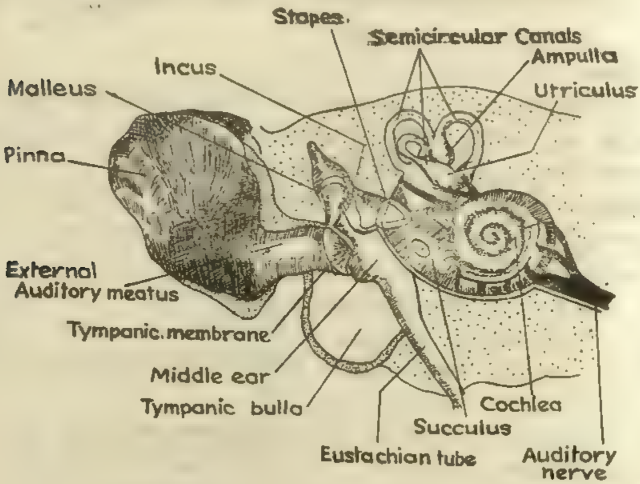


Fig. 64. Diagram of the ear.

Eye—The eye consists of a roughly spherical structure—the eye-ball (Fig. 65). It is protected by upper and lower eye-lids which are again provided with eye-lashes. There are six muscles which move the eye-ball in various directions thus facilitating vision. Its wall is composed of three layers—(i) outer **sclerotic,** (ii) middle **choroid** and (iii) inner **retinal.** In the exposed portion of the eye-ball, the supporting sclerotic coat is transparent and slightly bulged out. This is known as **cornea.** The choroid coat in this region is open and the circular aperture which lies behind the cornea is known as the **pupil.** The portion of choroid surrounding the pupil is known as **iris.** It is composed of circular muscles. Just behind the pupil is a **lens** which has convex surfaces both in front and behind. The cavity of the eye-ball is divided into two chambers; the anterior one in front of the lens is filled with a watery fluid known as **aqueous humour** and the posterior chamber behind the lens is filled with a jelly-like **vitreous humour.** Light rays enter

the eye-ball through the transparent cornea and then the rays are focused by the lens on the retina—the sensitive layer. These give rise to impulses which are conveyed to the brain through the fibres of the optic nerve and produce the sensation of vision.

Accommodation or the adjustment of the eye to distant and near vision is brought about by the lens. The lens is enclosed in a fibrous capsule which is attached all around by a suspensory ligament to the **ciliary body.** To this body the iris is also attached. In the ciliary body there are ciliary muscles in the form of a

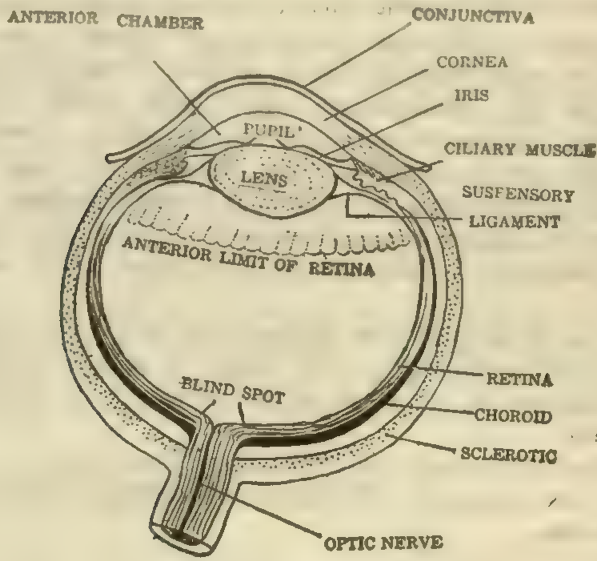


Fig. 65. Diagram of the eye.

complete ring. All these are parts of the choroid. The normal tendency of the eye-ball to maintain a globular form produces a tension or pull on the lens capsule which serves to flatten the lens and the eye is thus normally focussed for distant vision. Accommoda-tion for near vision is effected by increasing the convexity of the lens. During this, the ciliary muscles contract and pull forward the margin of the choroid. This releases the pull on the lens capsule. The elastic lens, as a result, bulges and becomes more convex. The divergent rays from the near object are thus focussed so as to form a clear image on the retina.

3

GENERAL IDEA ABOUT ECONOMIC ZOOLOGY WITH REFERENCE TO SERICULTURE AND APICULTURE

There are innumerable kinds of animals in the whole world. Some of them are benificial while others are harmful to man. Man depends on many beneficial animals for food, clothing (silk, wool), leather, lac, etc. Those animals which yield various substances of economic importance are known as economically important animals. The branch of zoology which deals with the study of economically important animals is known as **economic zoology.** Harmful animals which cause various diseases and heavy losses of crops and/or household articles are also considered under economic zoology.

Various kinds of silks are obtained from the cocoons of different types of silk worm moth. The branch of science which deals with the culture of silk worm and production of silk is known as **Sericulture.**

Honey and bees-wax are obtained from honey bees and for this purpose bees are reared. The process of rearing of bees is known as **Apiculture.**

SERICULTURE

Since time immemorial silk has been known as the best known fabric. Silk is produced from silk moths which belong to the order Lepidoptera. Silk moths are related to butterflies. These moths are cultured from early times. Their culture started in China nearly five thousand years ago and from there gradually spread throughout the world.

In India also, silk has been produced from early times. There is a great demand of Indian silk from different parts of the world and as a result there has been need for expansion in the production of silk in India.

The annual production of silk throughout the world has been estimated to about 40 thousand tons. Japan is the largest silk producing country of the world. China, Italy and India are impor-

tant silk producing countries. In India, there are silk industries in the states of Kashmir, Karnatak, West Bengal and Assam.

The silkworm, **Bombyx mori** is the most important silkworm and is reared in India, China and several European countries. This species is extensively cultivated in Kashmir, some districts of Punjab and West Bengal. *Bombyx mori*, lay their eggs on mulberry plant and the caterpillars feed on the leaves of mulberry. The larvae produce cocoon from which silks can be obtained. Due to the domestiction of *Bombyx mori*, for a very long time it is rarely found in wild condition and is considered as absolutely domestic.

According to the number of life cycles occurring per year mulberry silkworms are divided into two groups, namely, uni or bi-voltine and multivoltine. The uni or bi-voltine silkworms complete their life cycle only once or twice in a year. But multivoltine silkworms completes their life cycle 4 to 5 times annually. The silk obtained from univoltine worms is white and its quality is very high. But for rearing of these worms a temperate climate is required. Temperature exceeding 27°C is extremely harmful. Univoltine silkworms are cultured in Kashmir, Punjab and European countries. The silk produced by multivoltine worms is yellow in colour and its quality is not very good. Multivoltine silkworms are cultured in West Bengal, Assam and Karnatak.

Life history of silk moth and its rearing

Structure

The body of adult silk moth consists of three parts, namely, head, thorax and abdomen. On the head there are a pair of compound eyes and a pair of feathery antennae. Two pairs of wings are attached with the thorax. The abdomen is comparatively large, particularly in female. The mulberry silk moths are gray in colour.

In the month of May and June just after emergence both male and female moths (Fig. 66) mate.

Egg—One female lays about 900-1000 eggs in cluster. Each egg is like a pin head and yellow in colour. The egg (Fig. 66) is often called silk seed. The incubation period for eggs of multivoltine moths is 7-12 days but the eggs of univoltine moths require nearly eight months to form larva. The eggs of univoltine or bivoltine moths can be stored or artificially hatched by treating with hydrochloric acid.

Larva—The body of young caterpiller (Fig. 66) consists of 3 parts, namely, head, thorax and abdomen. In the head there are one pair of antennae and six pairs of simple legs. In the thorax there are three pairs of true legs. The abdomen possesses five pairs of false legs.

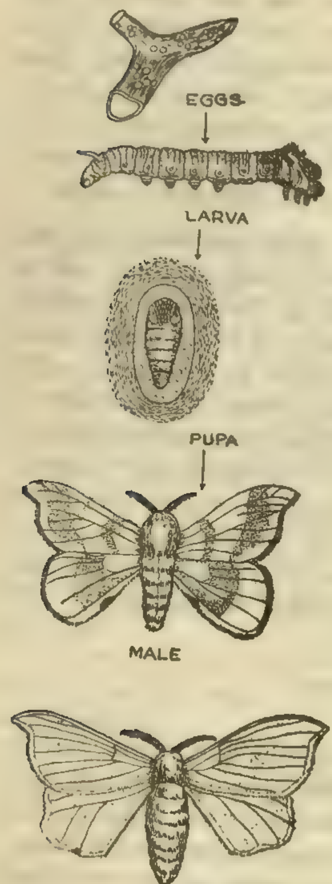


Fig. 66. Various stages of development of Silk moth (*Bombyx mori*).

The young caterpillars are placed in trays containing mulberry leaves (Fig. 67). Generally the cultivator prepares trays (rearing trays) with split bamboo of different sizes. Usually in 1 bigha land one ghara (that is, 16 racks each having a 2 m×1.2 m tray) caterpillar can be kept. The trays with caterpillar should be kept in shed, preferably in a rearing room. A 5 m×4.5 m rearing room can accomodate two gharas of caterpillar. The rearing room (Fig. 68) should be provided with varandahs on all sides and fly proof nets on the windows and doors. Foods are given at suitable intervals usually 4 times per day. The trays should be cleaned daily. Disinfection of the rearing room and equipments can be done by using a mixture of 1 part of 4% formalin with 19 parts of water. As the caterpillars eat voraciously they grow very quickly and become about 5 cm. long. The white mature larvae are placed in split bamboo baskets where the larvae take suitable shelter for cocoon formation. During growth the caterpillar sheds its exoskeleton and this process is known as *moulting*. The larval stage generally extends from 30-40 days. During this time the caterpillar sheds its exoskeleton four times. The caterpillar becomes almost motionless and does not take food during moulting. The stages before and after each moulting are known as *instar*. Just before the caterpillar

moults for the first time the silk glands attain full maturity. After the caterpillar finishes fourth moulting the larva stops eating and begin to secrete silk from silk glands around its body. The fluid exudates from the silk glands and hardens when it comes in contact with air and forms silk threads. A larva produces 15 cm. silk threads per minute. The larva has to spin around 60,000 to 300,000 times for producing a complete cocoon. The male larva has a small

Fig. 67. Two types of mulberry (*Morus*) leaves.

pointed spot on the ventral side of the last segment of the abdomen, whereas the female larva has four spots on the last segment of the abdomen. Paddy straw or other types of supporting materials should be provided for caterpillars to attach their cocoons. A complete cocoon is produced within 3-4 days.

Pupa—After fourth moulting and fifth instar the larva is converted to pupal stage (Fig. 66). Pupal period is completed in 9-14 days. The male pupa has a 'point' like spot on the last segment of the abdomen and the female pupa has a 'X' like spot.

Imago or **Adult**—Ultimately the pupa is converted into an adult moth within the cocoon. The adult moth secretes certain fluid which dissolves a part of the cocoon. Through this aperture the moth comes out.

Just after emergence the male and female moths mate. For the completion of the life cycle of silk moth a minimum time of two months is required. During this period the moth passes through four stages, namely, egg (10 days), larval stage (40 days), pupal stage (10 days) and imago moth. The male moths are active and comparatively small. The female moths on the other hand are comparatively large, lazy and with a prominent posterior part.

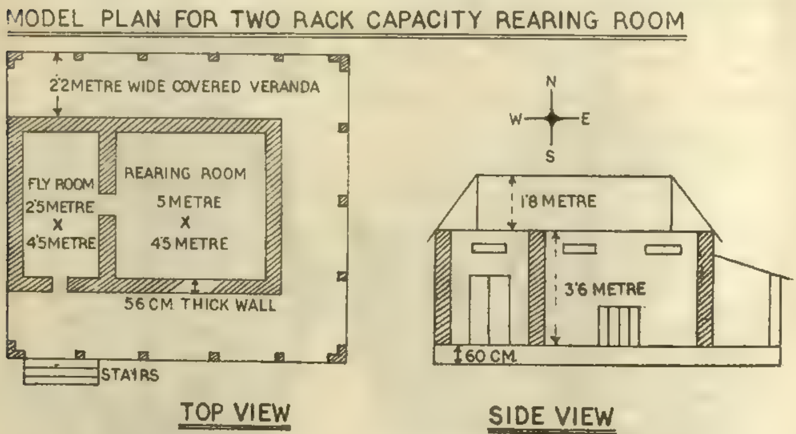


Fig. 68. Structure of an ideal rearing room, top view and side view.

Mulberry Plant—For the culture of silk moths mulberry plants —(*Morus spp.*) are necessary as these moths feed on mulberry leaves (Fig. 67). There are several species of *Morus,* namely, *M. alba, M. nigra, M. rubra, M. indica, M. tartarica,* etc. Mulberry plants are perennial and usually grow on loamy soil and in areas with high rainfall and proper irrigation. Before planting mulberry seedlings the soil is thoroughly cultivated and suitable amount of manures, such as, nitrogen, phosphorus and potassium salts or farmyard manures are added. Then cuttings are planted during the month of September-October in rows. As the silk worms prefer young leaves for food prunning of mulberry plants is done usually thrice in a year.

Silk threads from cocoons

About 9 gms. of silk seed yields nearly 9-11 kg. of green cocoon or 5-7 kg. of dry cocoons. For obtaining silk the cocoons are placed in boiling water or treated with hot air for 12 hours. The hot water kills the pupa inside. Besides this, the hot water treatment helps to uncoil the silk threads. Thread obtained from the outside of

the cocoon is uneven and this thread is spun to form silk threads. Such silk is known as spun silk. On the other hand, the silk thread obtained from the inner side of the cocoon is good and is reeled in a spool. This silk is known as reeled silk. Usually a cocoon of univoltine moth yields 614.7 metres of silk thread, whereas a cocoon of multivoltine moth produces 308.7 metres of silk thread.

Diseases of silk moth & control measures

(a) The most important disease of silk moth is known as *pebrine* which is caused by the protozoa *Nosema bombyces*. The disease spreads from one generation to the next generation through the female moth. The infected larvae do not grow properly and are irregular in shape. It can never spin and produce silk. The infected moths have deformed wings. The diseased females lay less number of eggs in heaped condition. The infected females and their eggs should be immediately destroyed.

(b) *Flacherie* is a disease of silk moth caused by bacteria. The diseased larvae have black streaks on their body and they ultimately die. The diseased larvae should be fed with leaves treated with bleaching powder.

(c) *Grasserie* is a disease of silk moth caused by virus. The infected larvae swell and become restless and yellow in colour. Eggs should be treated with 1% sodium hydroxide solution for 2 minutes.

(d) Another important disease of silk moth is *muscardine*, which is caused by fungus. The infected larvae become mummified and stiff. 5% formaline mixed with burnt husk is used for controlling the disease.

(e) *Tricholyga sorbillens*, which is commonly known as uzi-fly causes a serious disease of silk moths. These flies lay their eggs on the larvae of silkworms. The eggs after hatching produce larvae. The larvae of the fly enter within the body of the caterpillars (larvae) of silkworm and destroy their tissues and ultimately the larvae of the fly come out killing the caterpillars. The windows and door of rearing room should be provided with fly proof nets in order to prevent this disease.

Besides *Bombyx mori* silk can be obtained from some other silk moths, such as, Tassar silk moth, Eri silk moth, etc.

Tassar Silkworm (*Antheraea paphia*)

It is not a systematic culture because this pest can not be domesticated. Sal (*Shorea robusta*) and ber (*Ziziphus mauri-*

tiana) are the important host plants. As the caterpillars can not be domesticated the cocoons have to be collected from the jungle. Pupae inside the cocoons should be killed by boiled water.

Muga Silkworm (*Antheraea assama*) is cultured in Assam.

Eri Silkworm (*Philosamia ricini*).

This is common in Assam and West Bengal and the moths feed on castor leaves and bred in all places where castor is cultivated. The caterpillar flourishes in warm and damp climate. The cocoons cannot be reeled, so the killing of pupae inside the cocoons is not required. This type of silk gives durable silk cloth.

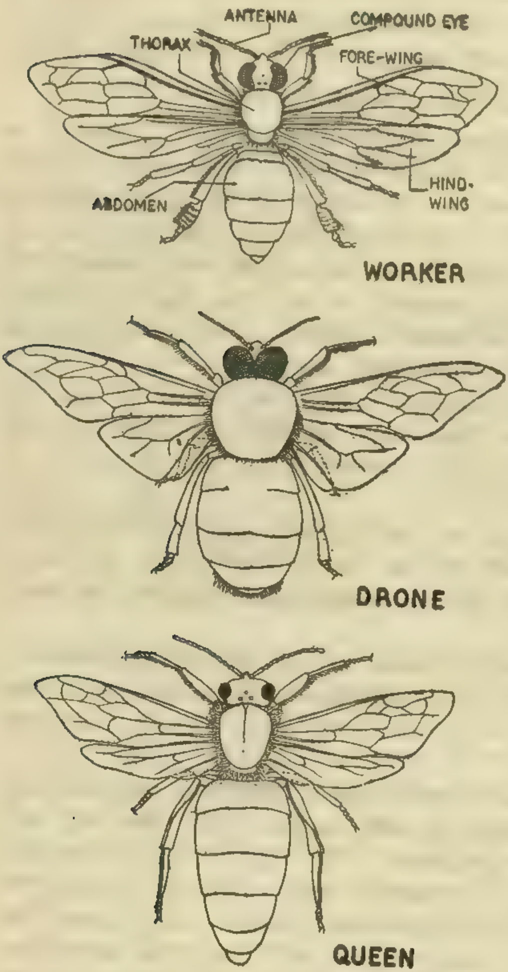


Fig. 69. Three forms (worker, drone and queen) of honey bee.

APICULTURE

Apiculture (Latin : *apis*—bee, *cultura*—culture) means bee-keeping. Honey bees are reared for obtaining honey and wax. Honey bees are benificial insects and live in colonies with a highly organised system of division of labour in which individuals perform specific duties. In each colony there are three kinds of bees, namely **queen**, **workers** (sterile females) and **drones** (males) (Fig. 69). Generally one egg-laying queen, a few hundred drones depending on seasons

and 20,000 to 50,000 or even a little more workers live in a colony. The queen actually controls the whole colony.

There are four species of honey bee, namely, *Apis indica (A. cerana)*, *A. mellifera*, *Microapis florea and Megapis dorsata*. In India usually *Apis indica* is reared. Besides these, *Melipona* a kind of small bees found usually in Assam and Meghalaya prepares small quantities of special quality honey in small honey combs.

Apis indica is found all over India. They have a quiet nature and so they can be easily reared. The hilly types can produce nearly 4.5 kg. of honey per hive annually, whereas those inhabiting the plain produce near about 1.5-2.5 kg. honey in a hive per year. They do not have a tendency for swarming (emigration).

A. mellifera is reared throughout the world particularly in America and Canada. They are calm and build hives in closed places. In an apiery usually 45-180 kg. of honey are obtained annually from these bees. They do not show a tendency for swarming.

Microapis florea is found in plains of India. They are very small and often called "little bees". They build very small hives (15-17.5 cm) and one hive can produce approximately 0.5-1 kg. honey per year. They are calm and form hives in forests and domestic areas.

Megapis dorsata or giant rock bees are found in hills and plains of India. They produce large hives (about 60 cm. high and 180 cm. wide). One hive can produce an average 37 kgs. of honey annually. These bees are of violent nature and cannot be reared. They build hives on the branches of tall trees or on the ceilings of deserted buildings.

Structure of honey bee

The body of a bee is made up of **head, thorax** and **abdomen.** On the thorax there are three pairs of legs and two pairs of wings (fore and hind wings). The fore and hind wings on either side are connected by hooks and grooves. As a result the fore and hind wings of each side move together during flight.

The food sucking tube is formed by a well-developed tongue or *labium* enclosed by *labial palp* and *maxilla* (Fig. 70). Worker bee draws in nectar from the flowers by the tongue. The elongated mouth parts remain folded when they are not in use. In such conditions the stout, short mandibles can chew pollen, shift wax and defend the intruders.

The posterior leg of a worker is provided with a curved hairy pollen busket, a pollen press and pollen comb (Fig. 71). Besides this, it has a wax gland and a honey sac in its abdomen.

In each worker and queen there is a sting connected with a poison gland at the posterior end of the body. The drones have no sting and the posterior end of the abdomen of every drone is blunt.

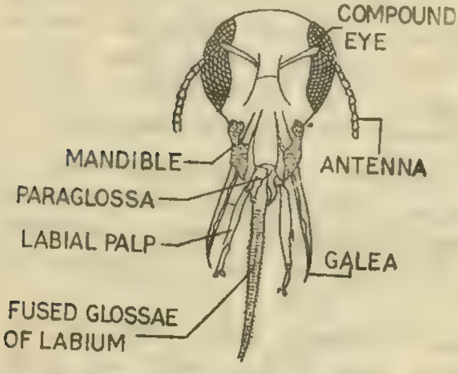


Fig. 70. Head and mouth parts of worker honey bee.

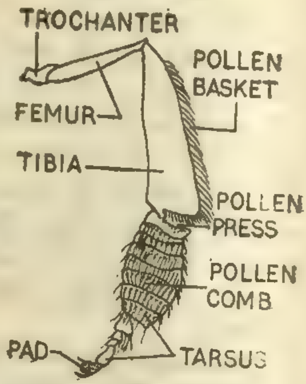


Fig. 71. Structure of hind-leg of worker honey bee.

A short description of three different kinds of honey bee is given below.

Queen—A mature queen bee can be easily recognised by its large abdomen and it may live from 2 to 5 years. Queen of honey bee colony is the mother of the colony and all drones and workers are her offsprings. She can lay 1500 eggs per day, each being placed in an empty cell build by the workers. She cannot feed herself and the workers feed her by special secretion, known as *royal jelly* and also honey and pollen grains. When 5-7 days old she mates with a drone, the male bee, in the air. The queen mates usually once or sometimes twice in her life time. The flight during which it mates with a drone is known as *nuptial flight*. The sperms are kept in the sperm sac. After mating is over, she kills the mating partner and returns to the colony and takes rest for sometime. Then the queen begins egg laying. She can lay both fertilized and unfertilized eggs.

From the unfertilized eggs only drone are produced but from the fertilized eggs workers and queen are produced. The differences between the workers and queen are in the quality and

quantity of the food fed to the larvae. The type of cell in which they develop also differs (Fig. 72). The workers larvae develop in small worker cells, whereas the queen larva develops in large queen cells. All larvae are fed on royal jelly for first three days. The larva in queen's cell continues to be fed on royal jelly throughout its life, but those in worker cells or drone cells are fed on a mixture of dilute nectar and pollen. So although there is no difference in the type of eggs or young larvae in workers and queen cells, but the difference during their development with regard to food results in their becoming either workers or queen bee.

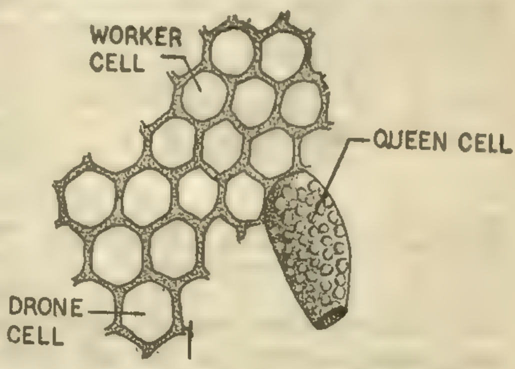


Fig. 72. Different types of cells from a beehive showing worker cells, drone cells and queen cell.

When the store of sperms becomes exhausted the queen can lay only unfertilized eggs from which only drones develop. When a queen lays gradually fewer number of fertilized eggs then the workers prepare a new queen cell where the queen lays one fertilized egg. From this a new queen develops which takes rest for few days. A group of workers always take care of her and feed her with the royal jelly. The new queen bites a hole in any other queen cell of the hive and its occupant is stung to death. For a few days the new queen leaves the hive for short flights. During one of these flights she is followed by large number of drones. She eventually mates with one of the drones, which dies after mating. She now comes back to the hive and starts egg laying. Usually the old queen with a number of workers leaves the beehive (swarming) before the emergence of the new queen.

Drones—Male honey bees are called drones. They live for about 5-6 weeks. Drones are inactive. They are fed by the workers or they themselves take pollen or nectar. Generally one drone takes five times more honey than a worker. The only function of drones is to fertilize a new queen. Drones are usually produced during breeding season (in spring and summer) when

newly emerged queen is to be mated. After the nuptial flight of the queen some drones may live in the hive, but with the approach of autumn all drones are ejected and killed.

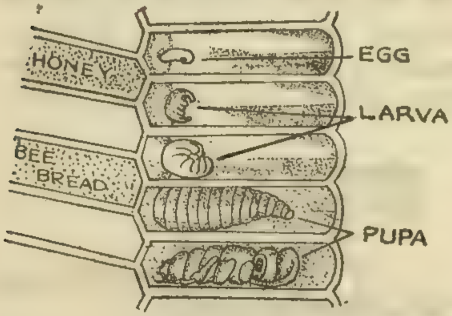


Fig. 73. Inner view of the beehive showing various stages of development of honey bee and food storage cells.

Workers—The workers are imperfectly developed females. They always work for the betterment of the hive. They cannot produce any offspring due to their imperfect development. Each worker performs various types of works. In young stages she cleans the combs, feeds the developing larvae and the queen, makes wax cells, stores honey and guards the hive. Later, she is employed in the field work and she searches and gathers nectar, pollen, etc. from the flowers. Those workers which collect food from outside are known as *foragers*. A short description of the various types of works performed by workers of different age groups are given below:

Age of the worker		Works performed
1-3 days	...	Cleans the combs.
4-9 days	...	Acts as nurse and looks after the developing larvae, feeds the larvae with royal jelly or with honey and feeds the queen bee.
10-16 days	...	Prepares new combs with wax formed by its own wax glands.
17-19 days	...	Prepares honey from the nectar collected by other workers, stores honey, cleans combs and keeps the combs cold by fanning of wings.
21-25 days	...	Guards the hive and protects the hive from intruders.
25 days onwards	...	Works as forager and collects nectar, pollen from flowers and brings them to the comb.

During peak period the workers live for only six weeks, but on average they live for 50 days.

Development of honey bees—The honey bees pass through four stages of development, namely, egg, larvae, pupa and adult (Fig. 73). The queen lays one tubular white slightly elongated egg in each hexagonal cell of a comb. After 3-4 days a white

legless larva emerges out and is fed by the workers. The larva is ultimately transformed into a pupa. The adult bee emerges out form the pupa and finally comes out by cutting open the cell.

The life cycle of queen, drone and the worker honey bees belonging to the species *Apis indica* are given below:

Type	*Average time required to complete one stage*			*Total period*
	Egg stage	*Larval stage*	*Pupal stage*	
Queen	3	5	7—8	15—16
Drone	3	7	14	24
Worker	3	4—5	11—12	18—20

Yearly activities of honey bee

During winter honey bees do not perform any work. They live together in the beehive. They feed on stored pollen and honey. When the bees huddle together in a cluster they keep one another warm. The centrally placed bees stay warmer. They constantly move their wings, legs and abdomens thereby generating heat. After sometime the bees in the centre move towards the periphery and their places are taken by other bees. In this way they keep themselves warm even in very cold weather. At the onset of spring the bees begin to multiply rapidly. As a result of this there may be scarcity of space in the hive when some of the bees leave the old hive (swarming) and build a new one at a suitable place. During very hot days of May, June the honey bees do not breed. In very hot weather (over 30°C) older bees collect water and younger bees take and distribute this water in the hive; other workers then vibrate their wings creating air current. This helps the evaporation of water, thereby lowering the temperature of the beehive. During monsoon and autumn the bees multiply slowly. Before the onset of winter they collect enough food in the hives. This stored food is used during winter months.

Swarming—When the beehive becomes overcrowded the old queen with a large number of workers leave the hive. This phenomenon is known as swarming. Swarming results in the formation of a new colony. The queen usually alights on a tree branch not far from the old hive and the workers surround her. Scout bees go out in all directions in search of a suitable location for a new hive. After finding a favourable site the scouts inform this to the swarm of bees, which then moves off to the specific site, where a new hive is made.

Food and other substances found in the beehive

Honey—The foraging workers collect necter from flowers. This necter is swallowed and temporarily stored in the honey crop, which is a specialized part of the digestive system. In the honey crop salivary enzymes partially digest the sugar of the nectar. When the foraging worker return to the hive they regurgiate the nectar from the honey crop to the mouth parts of younger workers, who processed the nectar into honey. These workers repeatedly swallow it, mix with enzymes and regurgiate it. By enzymatic action and with the evaporation of water the nectar is ultimately converted to honey, which contains only about 20% water as against 40-80% water found in nectar. The honey is stored in storage cells which are then capped and sealed with wax.

Pollen—As the bees move from flower to flower large quantities of pollen adhere to their fuzzy bodies. With the help of pollen combs on their hind legs they brush off the pollen from the body. The pollens are then rolled into compact balls by pollen press and are transferred to the pollen baskets of the hind-legs. The bees then return to the hive. The younger workers break pollen masses, store pollens in storage cells and cover them with a little nectar and finally seal the cells.

Bee bread—The workers mix up pollens with honey and prepare bread which is used as food for young larvae.

Royal jelly—It is secreted from special glands on the pharynx of young worker bees.

Besides food the workers collect or produce some substance which is required for building and maintaining beehive.

Wax—On the abdomen of the worker honey bees there are eight wax glands from which wax is secreted. This wax appears as scales and is scraped out by hind legs, cut, chewed and used for construction of the hive.

Propolis—It is a resinous substance collected from plants. Propolis is used for building protective walls of the comb.

Balm—Balm is like propolis but more dilute than the latter. It is used as varnish on the innerside of the cell.

Language of communication—The honey bee can pass information regarding the location of food by a peculiar type of dance (Forager's dance). After finding a rich source of food the workers perform the dance on the surface of the comb. By this dance they precisely indicate the direction and approximate distance of the place

from the hive. The speed of the dance indicates the distance of the source of food from the hive. Orientation of the body with respect to the food source and sun indicates the direction of the food source.

By dancing bees can also inform the location of suitable site for new hive during swarming.

Beehive—A beehive consists of many hexagonal cells made up of wax (Fig. 74). The cells or combs are arranged on both sides of a central plate. Usually the beehive hangs from the branch of a tree or from the cracks of wall. It is at first white in colour

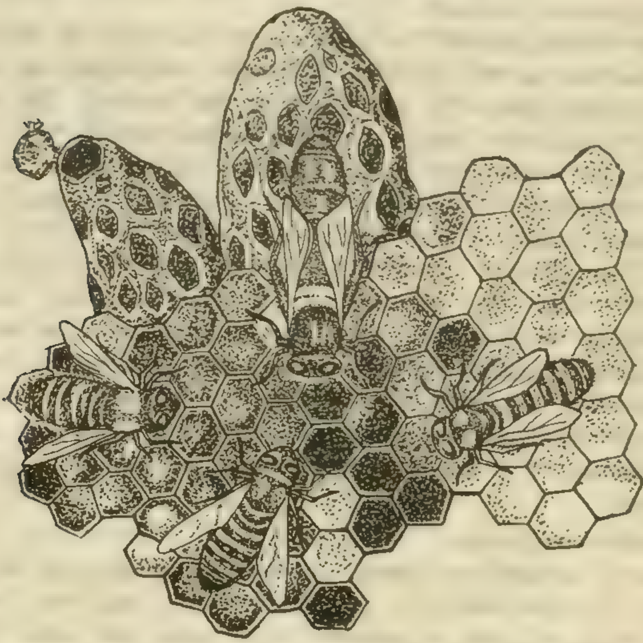


Fig. 74. Structure of part of beehive showing different types of cells and bees.

but later turns black with age. In the combs there are bees of various developing stages. In some cells pollen and honey are stored. The combs having any inhabitant or stored food are covered with caps. The structure of the cap is variable. Combs containing developing workers have flat caps, combs of drones have convex caps with central pores. Combs having food possess airtight caps. On the cells of the upper side of the beehive food is stored, whereas the lower combs contain developing bees. There are three types of cells in a hive. The workers' cells being

smallest (about 0.5 cm), drone cells (about 0.64 cm) are larger than workers' cells (Fig. 72). The queen cell is the largest and is situated at one side of the hive. It has an elongated structure. The combs, where food is stored is small.

Beekeeping—Man can exploit the activites of honey bee for obtaining honey and wax. For this, a suitable place (such as, a box) is provided for making the hive. This can be opened and examined easily without disturbing the honey bee.

There are various methods of beekeeping. A short description of some of them are given below.

1. *Indegenous methods*

(a) *Fixed* chamber is prepared on the side of the wall. This chamber has two openings. Through a small pore the honey bees can enter inside the box and build the beehive. The larger opening on the other side is meant for looking into the hive.

(b) *Movable* empty boxes or hollow tree trunk can be kept on the varandah. The honey bees can build beehives within these. Sometimes beehive is kept in a forest, when bees begin to live in this hive then the whole beehive is placed in fixed or movable chamber. After the collection of sufficient honey the beehives are smoked or sprinkled with water in order to drive out the honey bees. Then the beehives are squeezed with a piece of cloth for extracting the honey. But this method is unhygenic because in this process along with honey, the body juice of larvae, pollen, wax and excreta of bees become smashed and get mixed up with the honey.

2. *Modern methods*

(a) A movable two storied box for bee keeping can be prepared. It is provided with a firm foundation sheet for beehive. This foundation sheet is prepared with pure bee wax. It has combs for workers, queens, etc. The comb for the queen is so prepared that the workers can go to the queen's chamber and the queen can easily go to other combs and lay eggs, but the queen and drones can not came out of the hive. For extracting honey foundation sheets are placed on the honey extractor machine. After the extraction of honey the honey combs remain intact and the same foundation sheet can be used repeatedly.

(b) Scientifically prepared small movable wooden boxes are also used for bee keeping. These boxes are provided with beehives and can be kept in some lonely corner of the house or varandah. For commercial purpose this method is uneconomic.

Ideal place for bee keeping—In the vicinity (within a radius of 1.5-2.5 cm) of apiary there must be abundant flowers having nectar and pollens. The blooming time of such flowers is also an important factor for bee keeping. Plants like, margosa, tamarind, eucalyptus etc. yield nectar; whereas wild anar, jowar, bajra etc. are the source of pollens. Both nectar and pollens can be obtained from many plants, namely, balsum, water lily, lotus, Indian plum, pear, cherry, apple, peach, etc.

Diseases of bees—A short description of the various types of diseases and enemies of bees is given below.

Diseases of adult bee—The diseased bees usually can fly only upto short distance. They fall on the ground and ultimately die. Bees are attacked by various fungi, such as, *Mucor*, yeast, *Aspargillus*, etc. Their attack causes fungal diseases. A bacterium, namely, *Bacillus apiscepticus* causes septicaemia disease of bees. There are also a few other bacterial diseases. Amoebal attack produces amoebic diseases of bees. Viruses are the causes of paralytic disease of bees. Nosema disease is caused by a protozoon, *Nosema apis*. Besides *Acarapis woodi* (a mite) causes acarine disease of bees.

Diseases of young bees—Young bees are usually attacked by various types of epidemic diseases and the diseased bees usually die. Young developing bees are attacked by bacteria, fungi, etc. The foulbrood, sacbrood diseases are caused by *Bacillus alvei*, *B. para alvei* and *B. larvae*. Mycosis is caused by the fungus. *Aspargillus* and chalkbrood is caused by *Pericystis apis*.

Besides the above mentioned diseases honey bees are attacked by some pests. Of these black ant, wasp, wax moth, bee lice, rubber fly, toad, lizard, bird, bear, etc. are important enemies of bees. Black ants take away honey, pollen and young grubs from the hive. Wasps belonging to different species, namely, *Vespa cincta*, *V. ducalis*, *V. auraria* and *V. orientalis* kill bees. The caterpillar of wax moths (*Galleria mellonella* and *Achroia grisella*) hide below the beehive forming tunnels and eat considerable amount of bee wax. Bees are considered as food by some birds, toad, lizards, etc. Bear destroys the beehive in search of honey. So proper care must be taken during bee keeping for controlling various diseases and pests of honey bees.

4

MEDICAL ZOOLOGY

With the advancement of civilization man becomes interested about the causes and remedies of various diseases. It is now known that many diseases are caused by animals. On the other hand, various medicines produced from animals cure different diseases. Those animals which cause or spread diseases and animals from which medicines are produced are known as medically important animals. The study of medically important animals is known as medical zoology.

Some animals directly cause diseases, others carry the disease producing organisms in their body and later transfer it to human body causing diseases. One of the most common diseases, namely, dysentry, is caused by unicellular *Entamoeba histolytica,* which lives as endoparasite in the intestine. Diseases like cholera, typhoid, malaria, plague, etc. are spread by various insects in tropical countries. Malaria is caused by mosquitoes which carry the malarial parasite-*Plasmodium.* Until 1947 about one million people died of malaria every year. But due to national malaria control programme in 1953 and national malaria eradication programme in 1958, now a days malaria cases have decreased considerably. The sleeping sickness of Africa is caused by the protozoa *Trypanosoma gambiense* which is carried by Tsetse fly, through which the protozoa enters in the human blood and causes sleeping sickness. With the advancement of medical zoology the diseases caused by animals are very much on the decrease.

Various medicines are produced from animals. Hirudin, produced from the saliva of the leech *Hirudo medicinalis* can prevent blood coagulation. Cod liver oil and Halibat oil are used in diseases of vitamin deficiency.

Since mosquitoes are responsible for causing various diseases the medical importance of mosquitoes is briefly discussed.

MOSQUITO

Mosquito belongs to the order Diptera under the phylum Arthropoda. Mosquitoes (Fig. 75) act as vectors of various disease producing parasites. Different kinds of mosquitoes are responsible for several diseases of man. (*Anopheles* mosquitoes cause malaria. *Culex fatigens* is the vector of filariasis.) Different species of *Aedes* mosquitoes are the carriers of the parasites of

yellow fever and dengue fever and transmit these parasites to human body.

The male mosquitoes live on the sap absorbed from different parts of plants. But the female mosquitoes suck blood from man and other animals. For this, the female mosquito has

Fig. 75. A *Culex* mosquito.

piercing and sucking mouth parts. Thus, only the female mosquitoes can spread diseases. Like males, the female mosquitoes can also feed on plant juice.

Structure

The body of a mosquito consists of head, thorax and abdomen. On the head there are two compound eyes and two hairy antennae. Different mouth parts, namely, labrum, labium, hypo-pharynx, a pair of mandible and maxilla together form the proboscis by means of which the female mosquito can suck blood and the male can absorb plant juice. Maxillary palps remain free, and can be found on either side of the proboscis. The tip of the maxillary palps of male *Anopheles* are broad and blunt but the females have long pointed maxillary palps. In *Culex* the females have small maxillary palps, whereas the males have long and pointed maxillary palps. On the thorax there are three pairs of long narrow legs and a pair of well developed wings. The abdomen is narrow and elongated and is made up of eight segments.

Life history

The mosquito passes through four stages of development in its life cycle. The stages are egg, larva, pupa and adult stage (Figs. 76 & 77). The first three stages take place in water.

Egg—Female mosquitoes lay their eggs on the surface of stagnant water. *Anopheles* mosquito lays its eggs usually in slow flowing or stagnant comparatively clear water having algal blooms, whereas the *Culex* mosquito lays the eggs in stagnant and dirty water. At first the egg is white in colour but later becomes blackish

and hard. The eggs of *Anopheles* mosquito occur singly and are provided with air floats. About 200-300 eggs are laid at a time by an *Anopheles* mosquito. The eggs of *Culex* are found in groups. A female *Culex* mosquito lays about 200-400 eggs at a

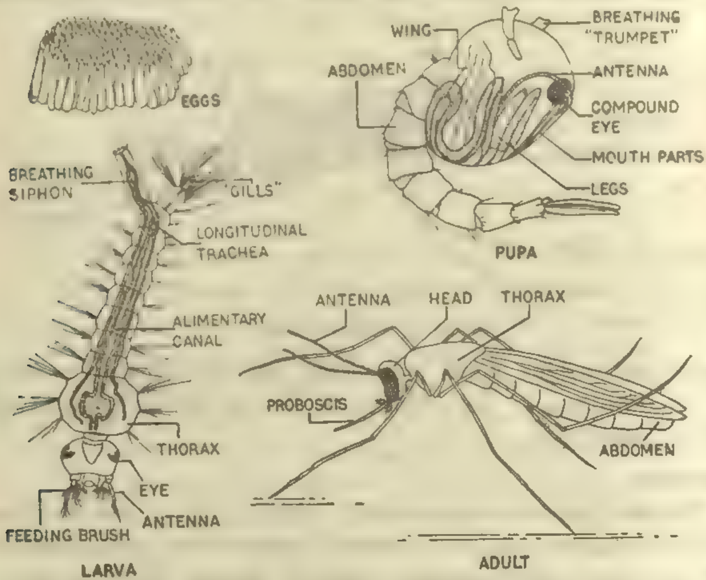


Fig. 76. Life history of *Culex* mosquito.

time. The eggs are pushed into position by hind legs and glued together to form a raft. Air bubbles trapped in between the eggs make the raft buoyant. Each egg of *Culex* is more or less cylindrical and broader at the base. The base is provided with a knob (swelling). The eggs hatch after 2-3 days and larvae are formed.

Larva—The larvae are active and can dive in water. They feed on plankton. The body of a larva consists of head, thorax, and abdomen and is covered by hairs. There are a pair of eyes, a pair of feeding brushes and a pair of antennae on the head. The feeding brushes help the larva in taking food. The abdomen consists of ten segments. From near the end of the abdomen the breathing tube projects. The larva of *Anopheles* floats parallel to the water surface whereas the larva of *Culex* lies vertically or obliquely with its head facing downward. The larva of both types of mosquitoes changes its case four times. Usually after about five days the larva is transformed to pupa.

Pupa—The pupa can swim and does not take food. It is comma shaped with a quite large head and thorax which together form

the large cephalothorax. The abdomen is composed of nine segments. The pupa breathes through a pair of breathing tubes, which pass through the pupal case above the thorax. The pupa of *Anopheles* has shorter breathing tube than that of the pupa of *Culex*. The breathing tube is meant for aerial respiration. The last abdominal segment is provided with a pair of flattened leaf

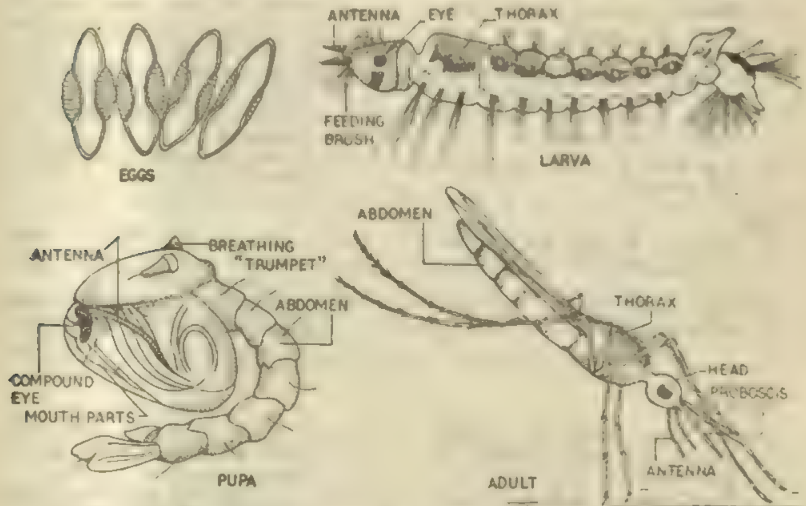


Fig. 77. Life history of *Anopheles* mosquito.

like appendages (fins) by means of which the pupa can swim. After 2-3 days an adult mosquito is formed. Most of the pupal structures are used up as nutritive material for the formation of the adult fly. When the adult is formed the pupal case splits above the head and thorax. During this time the pupa comes near the surface and the adult fly ultimately emerges out.

Adult—After emergence from the pupal case the adult takes rest on the pupal case for sometime when its wings harden; after few minutes it flies away. There are some differences between adult *Anopheles* and *Culex* mosquitoes. *Anopheles* mosquito makes 45° angle with the surface when it sits. But a *Culex* mosquito places its body parallel to the surface when it sits.

The adult mosquitoes can live upto one month.

Differences between Anopheles and Culex mosquitoes

Structure

Anopheles	*Culex*
1. Smaller than *Culex*.	1. Comparatively larger.
2. Few hairs are present on the antenna.	2. Antenna densely hairy.

Anopheles	*Culex*
3. (a) Male has maxillary palp with blunt and broad end. (b) lemale has long maxillary palp.	3. (a) Male has long, pointed maxillary palp. (b) Female has small maxillary palp.
4. The wings have black and white striations.	4. No striation on the wings.
Habit	
5. When it sits the body makes about 45° angle with the surface.	5. When it sits the body is placed more or less parallel to the surface.
6. It lays eggs in comparatively clear water.	6. It lays eggs usually in dirty water.
7. While flying some sort of sound is produced.	7. While flying no sound is produced.
8. It acts as a vector of malarial parasite.	8. It acts as a vector of filarial parasite.
Egg	
9. Each egg is boat shaped and is provided with air float.	9. Each egg is cylindrical with a knob at the basal end; air floats absent.
10. Eggs occur singly; no raft is formed.	10. Eggs occur in cluster and are joined with one another by means of glue and form a buoyant raft.
Larva	
11. The larva floats horizontally placing its body parallel to the water surface.	11. The larva floats obliquelly with its head facing downward.
12. It collects its food from surface water.	12. It collects its food from comparatively deeper water.
Pupa	
13. Respiratory tube is comparatively short and broad.	13. Respiratory tube is comparatively long and narrow.
14. In comparison to *Culex* usually a greater part of the body remains in contact with the water surface while it floats.	14. Comparatively smaller part of the body remains in contact with the water surface while it floats.

Diseases caused by mosquitoes

Malaria—*Anopheles* mosquitoes carry the malarial parasite *Plasmodium* and transmit the disease malaria. *Plasmodium* is a unicellular endoparasite, which invades the red blood cells and ultimately destroys these cells, producing regular fevers. When a mosquito sucks up the blood of a person suffering from malaria the parasites enter into the body of the mosquito. The parasites then grow and multiply in the stomach wall of the mosquito; the offspring then pass to its salivary gland. When such mosquito sucks the blood of another person, then it injects the parasites along with saliva into his blood stream. These parasites come in the liver and multiply. The offspring invade the red blood cells and multiply within the cells, which undergo lysis and the parasites again

invade new red blood cells. The person so infected suffers from malaria and when a mosquito sucks the blood of such person the parasite enters into its body. The parasite does not cause any harm to the mosquito.

Filariasis—This disease is widespread in India. This is caused by the round worm. *Wuchereria bancrofti. Culex* mosquitoes act as vector of the disease. If a mosquito sucks the blood of a person having filariasis then the larval stage of the filarial worm enters into its body. The larvae grow within the body of the mosquito and if such a mosquito bites another person', then the filarial parasites enter into his body. The worms enter in the lymph vessel and ultimately come to the lymph nodes where they are transformed to mature worms. When both male and female worms are present in the bory of a person and if sexual reproduction takes place then many worms are produced. These worms ultimately close the lymph vessels and thereby disturb the lymph flow. As a result of this the legs gradually swell and filariasis develops. Besides the legs, other parts of the body may be swollen.

Control measures

As mosquitoes are harmful insects and cause various diseases, suitable measures should be taken to control the mosquitoes. Some of the measures commonly practiced are given below.

1. Swamps, marshes and other stagnant water, which are the breeding ground for mosquitoes should be cleaned and drained.
2. Stagnant waters should be sprayed with kerosene and insecticides, which form a thin film on the surface of water. The larvae and pupa of mosquitoes die in such water for want of oxygen.
3. In ponds where insecticides cannot be applied (as the insecticide is poisonous) biological controls, such as, keeping larvae eating fishes, should be introduced.
4. DDT and other insecticides should be sprayed in the house for killing adult mosquitoes.
5. Mosquito nets and curtains should be used to prevent the entrance of mosquitoes.
6. Mosquito repellant cream can be used to protect human bodies from mosquitoes.
7. Investigations are going on for genetic control of mosquitoes. The plan is to release sterile males in the environment. If such male mosquito mates with a female then the female will become sterile.

5

AGRICULTURAL ZOOLOGY

Primitive men wandered from place to place and obtained their foods by hunting animals, catching fishes and by getting fruits from plants. With the progress of civilization there was an increase in population and men gave up their wandering habit and began to live together in particular places, namely, villages. They then felt the increasing demand for food for the growing population and started cultivating selected plants and domesticated and reared certain animals. Agriculture (Latin: *ager*—a field, *cultura*—cultivation) i.e., the cultivation of various plants, is related to zoology. The science which deals with agriculturally important animals is known as agricultural zoology.

The cultivation of rice, wheat, jute, etc. are affected by certain pests. So for preventing attack of pests a knowledge about these animals is essential. It has been found that 50% of the total agricultural products are lost due to attack by various pests. For rearing various animals plants are required as food. So a knowledge in agricultural zoology is essential for crop production and for rearing animals.

PISCICULTURE

Fish is one of the major food of human beings and is rich in protein. Beside protein, fish also contains calcium, phosphorus, iron, oil, etc. It is found in various water bodies, such as, ponds, beels, lakes, rivers, streams, oceans, etc. Due to increasing demand of fish as human food and uncertainty of fish capture from natural sources it is now become essential to culture fishes artificially.

The total amount of fish catch (inland and marine) of the world has increased from 19.6 million tons in 1948 to 65.6 million tons in 1972. In India the amount of fish catch annually is much less than that of other countries of the world. India's position varies from 7th to 9th among world's fish producing countries. In 1972 Japan was the leading fish producing country with annual catch of 10.2 million tons, Russia was second with yearly catch of 7.8 million tons, India was seventh with a production of 1.6 million

tons. Other major fish producing countries are China, Peru, Norway, U.S.A., Spain, South Africa, etc.

The fishery resources of India are vast and very rich. There are different types of sources from which fishes can be obtained. These are fresh water, brackish water, and marine. The fresh water system includes extensive river system, irrigating canals, reservoirs lakes, beels, tanks, ponds, etc. The brackish water includes the estuaries behind the mouth of the rivers, lagoons, etc. Fisheries have two faces, namely, capture and culture.

Fishery is usually divided into inland fishery and marine fishery. These two groups are again subdivided. The divisions and subdivisions are shown below:

Fisheries

- Inland
  - Pond culture (in ponds)
  - Riverine fishery (in river)
  - Estuarine fishery (in estuaries)
  - Lacuarine fishery (in big lakes)
- Marine
  - Costal fishery
  - Offishore and deep sea fisheries

Fish culture is mainly done on fresh water. Pisciculture (Greek: *Pisces*—fishes) is the culture of fishes in ponds, tanks, fresh water artificial lakes, etc. under controlled conditions. In pisciculture fish seed are sown, nursed, reared and harvested when grown to suitable size.

In India, culturable water area is vast, of these only a part is used for fish culture. Therefore, there is an urgent need for popularisation of pisciculture in India so that vast water areas available can be used for fish culture.

Pond culture

Kinds of fishes which can be cultured in the same pond— A number of compatible fishes of different feeding habit can be cultured in the same pond for obtaining maximum production. Such type of culture is known as composite fish culture or *polyculture*. In India, fishes, such as, *Catla catla* (a surface feeder and feed on plankton) *Labeo rohita* (a common mid feeder), *Cirrhinus mrigala* and *Labeo calbasu* (bottom feeders) are grown together. Besides these, other fishes which are cultured in pond include *Cyprinus carpio*, grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalamichthys molitrix*), *Tilapia mossambica* etc.

Fresh water prawn (*Macrobrachium rosenbergii*) belonging to the group Crustacea are also cultured in certain ponds. Grass and silver carps naturally occur in the rivers of China. They are introduced in India in 1959.

Usually 3750-5000 fry/fingerlings (about 5-8 cm. long) can be cultivated in one hectare pond. Fish seed can be released in pond from September to November.

Nature of the ponds

The area of the pond should be between 700-1150 sq. metre. Usually it is 30 metre long, 15 metre broad and 1.5 to 2.5 metre deep. The pond should have a drainage system. For complete draining out of water when required a drain pipe should be installed at the lowest point of the pond. The earthen embankments should have some extra height (10 to 15 metre higher than ground level) so that overflowing or washing out during heavy rains and floods can be prevented. It is good to have loose friable loamy bottom soil in ponds for pisciculture. In ponds having such soil, mineralization of organic substances occur rapidly, nutrients are easily absorbed retained and released slowly. This gives higher production. The water of the pond should be slightly alkaline having a pH between 7.5 to 8. The soil on the bank of the pond should be covered with grasses which can bind the soil to certain extent.

Aquatic weeds are removed from the pond in order to allow free movement of the fishes. Care must be taken for maintaining proper oxygen content of the pond and to prevent fish diseases. If natural food is not sufficient, artificial food like Rice bran ; Ground nut oil cake, etc. can be given.

Application of fertilizers

The productivity of ponds can be increased by addition of fertilizers, which provide nutrients, minerals, vitamins, etc. required for the rapid multiplication of microscopic organisms which directly or indirectly serves as fish food. Fertilisers are mainly of two types : inorganic and organic.

Inorganic fertilizers used for fish culture are (a) limestone and lime containing fertilizers, (b) nitrogen fertilizers, (c) potassium fertilizers, (d) phosphate fertilizers, (e) magnesium fertilizers and (f) trace elements (such as, manganese, boron, sulpher, iron, copper, zinc, etc.) fertilizers.

Organic fertilizers usually contain nearly all the nutrients required by the fishes. They enrich the organic content of the soil

and water, thereby increasing the fertility of the pond water. Compost manure or cowdung manure may be given. But there are some drawbacks of using organic fertilizers, such as, (i) it may trasmit parasites and diseases to the pond and (ii) excess organic fertilizers may facilitate the production of toxic gases, (iii) it may facilitate the production of algal bloom.

Preparation of the pond before releasing the fry

The bottom soil should be loosened. If the soil of the pond is acidic then it is treated with 250-350 kgs. of lime per hectare. Six to seven days after applying lime cowdung (1000 kg/hectare) may be applied. After this the pond is filled with suitable amount of water. Before the release of the fry the pH is tested and the amount of available food is estimated.

Collection of fish seed

Major culturable fishes (e.g., catla, rohu, mrigala, calbasu, etc.) breed during south-west monsoon months on the shallow banks of flooded rivers and adjoining areas. Besides rivers, major carps can breed in some reservoirs, artificially constructed bundh type tanks and through hypophysation. Some fishes, such as, *Tilapia*, Channa and *Cyprinus carpio*, etc. can breed in ponds. Of the total fish seed production in India collection from riverine system contributes about 90%.

Collection of fish seed is done during monsoon months from the shallow banks of the flooded rivers. Spawn are collected by funnel shaped finely woven nets, known as *shooting nets* which are placed in shallow water with their mouth facing the current. The narrow end of the net is provided with a split bamboo ring. A hood like or rectangular piece of cloth, known as 'gamcha' is tied around the ring. Then the net and the 'gamcha' are fixed in proper position with the help of bamboo poles. The spawn moving along water current collect in the gamcha from where they are removed periodically. The spawn are then sieved through a round meshed mosquito netting and are collected in muslin cloth. They are then kept in nearby hapas (for description see pp 290-291) for conditioning and temporary storage before distribution to nurseries.

For fish culture fish seeds can be obtained from Fishery departments. During transfer of young seeds to nearby places the water of the container (usually an earthenware container) is splashed repeatedly to prevent scarcity of oxygen. When the fish seeds are transferred to distant places then specially prepared containers are used.

For culturing fishes from egg to table size various types of ponds, namely, hatchery, nursery tank, rearing tank, stocking tank etc. are required.

(a) **Hatchery**—In the hatchery eggs are transformed to spawn. These are shallow ponds having a size of about $3 \times 1 \times 0.6$ metre. At the beginning of monsoon eggs are collected and placed in hatchery. Within 18-24 hours spawn or hatchlings are formed from the eggs and these are then trasferred to nursery tank.

(b) **Nursery Tank**—In the nursery tank spawn grows to fry. This tank is usually about 15 metre long, 7.5 metre broad and 1 metre deep and should be free from weed and predatory fishes and predatory insects. Besides these, algal blooms should be controlled. Proper fertilization of pond should be done for the production of zooplankton, which is a good food for the spawn.

As the spawn eat voraciously the amount of available food becomes very low within 2-3 days, so supplementary food should be supplied in the nursery tank. For spawn of major Indian carps usually finely powdered and sieved rice bran and oilcakes of ground nut or cocoanut or mustard etc. are given. Besides these, a mixture of dried, powdered, sieved aquatic insects, small prawns, cheap pulses may be supplied.

When the spawn becomes 2-2.5 cm. long (in 15 days with artificial feeding) they are transferred to rearing tank.

(c) **Rearing Tank**—In the rearing tank fry grows to fingerling. Rearing tank is about 15 metre long and broad and 1.5 metre deep. Weeds and predatory fishes should be removed from this tank. Proper fertilization of the tank should be done and there should be arrangements for supplementary feeding. Fry measuring about 2.5 cm. can be released from the nursery tank to the rearing tank where they are kept for 2 months. When the fingerlings are about 7.5-12.5 cm. long they are transferred to the stocking tank.

(d) **Stocking Tank**—Here, the fingerlings grow to table sized fishes. This tank should be free from algal bloom and predatory fishes. Proper manuring should be done. The water of the tank should be slightly alkaline.

Description of a 'hapa'

For artificial breeding of fishes and hatching egg, etc. a box shaped cloth container made up of fine meshed mosquito net is prepared. This container is known as 'hapa' and is provided with

a cover. Except the region through which the fishes are taken out or introduced, all sides of the 'hapa' are closed. This small open portion may be closed after introducing the fishes. The hapa is placed with its open part facing upward in about 1 metre deep water. The four ends of the hapa are fixed to four bamboo poles in such a way so that about 12-23 cm. of the net remains above water. The bottom of the net should not touch the muddy bottom of the pond. Usually the hapas are 2-2.5 metre long, 1-1.5 metre broad and one metre deep. There are two types of hapas, namely, breeding hapa and hatching hapa.

Artificial (induced) breeding of hypophysation

In India majority of fish seeds are collected from rivers and are available only at specific centres. There is also risadvantage in transporting the spawn with high degree of mortality during transit. Fish seeds from the riverine sources also cannot cope with the growing demand. Besides these, the spawn being of mixed type it may include uneconomic forms. In view of these, the fishes are artificially bred by hipophysation.

It has been mentioned earlier that rohu, catla and mrigala do not breed in stagnant ponds, but they do so when they are injected with aquatic extract of pituitary gland. This extract contains hormone which stimulates breeding.

For artificial breeding healthy fishes weighing about 1.5-5 kg. are chosen and are placed in separate hapa during monsoon months. For breeding those ripe males in which milt oozes when gently pressed are chosen. Females suitable for artificial breeding are those which have soft bulging rounded abdomen and reddish vent.

For preparing extract, pituitary glands are collected from fully ripe freshly killed male and female fishes belonging to the same or closely related species as the recipient during the month of July. Pituitary extract from fishes preserved in ice for 5-7 days also serves the purpose. The glands after taking out from the fishes are placed in absolute alcohol for dehydration. After a day the alcohol is changed for further dehydration and defattening. It is then kept in fresh absolute alcohol in a dark coloured bottle and stored in a refrigerator. Later, these glands are taken out and the alcohol is allowed to evaporate. The glands are then grinded to a fine powder in tissue homogenizer. This is then mixed with distilled water or 0.3% saline and centrifuged. The supernatant fluid is now ready for injection. In females 2-3 mg. of

pituitary extract per kg. wt. is injected. A second injection is given after six hours. In second injection the amount of extract to be injected is 5-8 mg/kg. wt. Male fishes are injected only once at the time of second injection of the female. The injection is given intramuscularly at the caudal peduncle or dorsal region near the base of the dorsal fin. The injected female and two injected males are placed in same breeding hapa for spawning. Five to six hours after second injection the female fish exudates eggs within the hapa. The male fishes at the same time discharge milt. In major carps fertilization is external and the eggs are fertilized within the breeding hapa.

The fertilized eggs are removed from the breeding hapa to the hatching hapa. The hatching hapa is actually made up of two hapas, small inner hapa having few holes and larger outer hapa. The hatching hapa is fixed in a pond having clear water free from algal blooms. 75,000-100,000 eggs are then uniformly spread on the inner hatching hapa. Most of the eggs hatch out within 14-18 hours after fertilization. Through the holes of the inner hatching hapa the hatchlings go to the outer hapa. After all the eggs are hatched and the hatchlings escape to the outer hapa, the inner hatching hapa is removed along with empty egg shells.

Diseases of carps

The carps usually suffer from various diseases. A short description of few major diseases are given below:

(a) *Saprolegnia parasitica*, a fungus attacks through the injured part of the fish and produces mycelium below the skin. This disease can be controlled by treating the infected fish with common salt solution (3%) or copper sulphate (1: 2000) or potassium permanganate (1: 1000) or malachite green for 5-10 minutes.

(b) Fungi (*Branchiomyces sanguinis*) belonging to the group Phycomycetes attack the gills and produce mycelium. As a result of fungal infection the gills disintegrate. There is no suitable control measures. In case of early stages of infection the infected fishes are treated with common salt (3-5%) or potassium permanganate (5 ppm) for 5-10 mins. In infected pond 12 kg. of copper sulphate/hectare can be used, when the average depth is 1 metre.

(c) Certain bacteria can attack the fins, which then rot. For controlling this disease infected fishes are treated with copper sulphate solution (1: 2000) for 1-2 minutes.

(d) Another important bacterial disease is ulcer. Ulcer on the body results in gradual exposure of body muscles. In early stages the infected fish is treated with copper sulphate (1 : 2000) solution, but at later stages the disease can not be controlled.

(e) *Argulus,* the fish lice lives as external parasite on fish epidermis. Due to infection of lice the fishes have stunted growth, their scales become loose and red spots appear on the body. During early stages of infection the fish is treated with 1 : 1000 glacial acetic acid for 5 minutes then with 1% salt solution for 1 hour. In case of severe infection the pond should be drained, dried and treated with lime.

(f) *Anchor worms* attack the fishes. The anterior part of the worm penetrates deep in the muscle of the host and only the posterior part can be seen from outside. These worms can be removed by means of a fine forcep and then treating the infected parts with potassium permanganate solution for 2-3 minutes.

(g) *White spot disease* (ichthyophthiriasis) is caused by the protozoan ciliates. On the skin, gills and fins of the infected fish small whitish cysts are seen. Infected fishes are treated with 2% common salt for 7 days. Ponds are disinfected with quicklime.

(h) *Asphyxiations,* a non-parasitic disease, is caused by supersaturation of dissolved oxygen. In infected fish small bubbles of gas accumulate beneath the skin, fins, around the eyes, in the stomach and intestine or in blood capillaries. Such fishes can not swim properly and ultimately die. Infected fishes should be removed to other pond having proper oxygen concentration.

PESTS OF PADDY

Pests are destructive or noxious organisms. Many insect and mite pests attack paddy plants and cause heavy losses. These pests are so varied that paddy plants can be attacked at every stage of growth. (In seedling stage (in nursery bed) paddy plants can be attacked by army worms, root caterpillers and grasshoppers. Young plants in the field can be attacked by leaf hopper bugs, leaf eating beetles, leaf rollers and case worms. Stems can be attacked by stem-boring caterpillars. Gall flies and blister beetles feed on pollen thus damaging the flowers. Developing grains are destroyed by ear-head bugs.) As paddy is cultivated over a wide range of climatic conditions most countries have some local pests. The worst pest of paddy is stem borer, but greatest total loss is caused by paddy bugs, which are most widespread.

In India West Bengal is one of major rice producing provinces. The important paddy pests are stem borer, swarming caterpillar, paddy bug, etc. These are known as major pests. Those pests which cause minor losses are known as minor pests. Rice case worm, rice jassids, paddy grasshopper, etc. are considered as minor pests. As it is not possible to give life histories of all paddy pests here, a short description of a few of them is given.

Rice stem borer (*Schaenobius incertelas*)

This is the most important insect attacking rice in India. The rice stem borer is reported to cause heavy loss. (The stem borers are the larval stage of small moths belonging to the genera *Schaenobius, Scirpophaga, Chilo,* etc. Shortly after hatching the larvae enter into paddy stems and live for most part of their life within the stems.) They feed on plant tissues thereby killing or seriously injuring the plant. The characteristic symptom of attack in the nursery plants and in the young growing paddy plants is the presence of "dead heart" or wilting of the central shoot. Formation of "white ears" is the result of attack in the ear head stage of the crop.

Fig. 78. Eggs of stem borer.

Schaenobius incertelas or yellow stem borers are nocternal. Their life cycle is completed in 43-61 days. The moths live only for 5-7 days. The larval period is completed in 30-40 days and the pupal period may last 6-10 days. These moths lay their eggs in clusters on the underside of leaves (Fig. 78). The female moths are bigger than the males and each of them may lay 2-3 egg clusters. Each cluster contains 50-150 eggs. The eggs are creamy white, flattened and oval and hatch in 5-8 days. Large number of eggs are preyed by birds, spiders, dragon flies, etc. and are also lost due to storm.

The newly hatched larvae move about on the undersides of the leaves and feed by scratching the tissues. But soon the larvae move towards the stem and bore into it just above the region where the leaf blade diverges from the leaf sheath. Several larvae may

enter the plant on which they are hatched and the rest are scattered in search for a host. For this they suspend themselves from threads coming out from their mouths. Some are blown by wind and some fall into the water. In this way, these are carried to a host. But usually only 10-25% larvae can find a host and others are lost.

The larva after eating the tissue of the uppermost internode bores through the nodes down into successively lower internodes (Fig. 79). When the whole stem is exhausted the larva comes out of the stem, migrates by floating on water and ultimately attacks another stem.

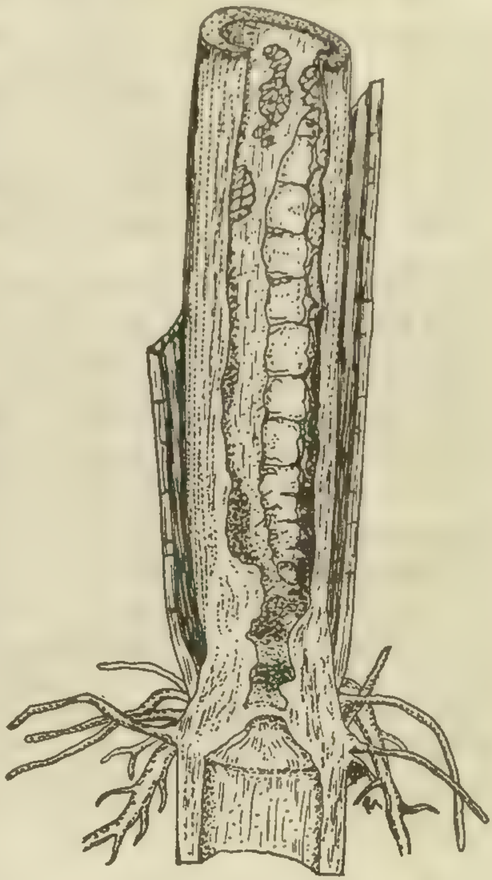


Fig. 79. A caterpillar of stem borer within the rice stem.

A nearly mature larva moves towards the base of the stem where it pupates. The pupation takes place inside the stem in a silken cocoon. Pupation generally takes place in flooded paddy fields and the moth comes out through a hole just above water level.

A number of larvae are not prepared for pupation when the plants are harvested and some of these die along with the drying of the cut plants but some others remain in the base of the stem where they hibernate.

The number of generations of the stem borer per year depends on the cultivation practice and climatic conditions. In areas where more than one paddy crops are grown annually there are usually 4-6 generations of stem borers. But where only one paddy crop is

the rule annually there we can find usually only two generations of stem borers per year. Thus the number of generations of this pest increases with the continued presence of the host in the field.

Control measures—(1) The hibernating larvae or pupae can be destroyed by ploughing the field immediately after harvesting.

(2) Light traps are sometimes used in Japan as stem borers are phototropic. But this method is not very successful.

(3) Destruction of eggs and injured plants by hand.

(4) Spraying with suitable insecticide at the critical period, gives good results. Spraying 0.13-0.19 lb. of endrin per acre once in the nursery plants and twice on the field crop can effectively control *Schaenobius incertelas.* Besides this, Thimet granule, Sevidol granule, Ekalux granule, BHC and Parathion can be used for controlling stem borers.

Control of stem borers by insecticides has three possible courses: (i) to kill the young larvae just after hatching by applying insecticides to the plants; (ii) by applying systematic insecticide for killing larvae and pupae present inside the plant, (iii) to kill the emerging moths and exposed larvae by adding insecticide to the water of the field. The first procedure is widely used. The second course of action is not so effective.

Other pests of paddy

2. **Rice Gall Midge** [*Orseolia* (=*Pachydeplosis*) *oryzae*]

In India the rice gall midge is second in importance only to the rice stem borer. The midge produces the characteristic "silver shoot" or "onion leaf" and consequently causing the death of the tiller. The adult is a small fly about the size of a mosquito. Copulation takes place just after emergence and adults live for 4 to 5 days. A female can lay about 100 eggs and eggs hatch in 3 to 4 days. The larval period is 8 to 18 days. Pupa is pinkish red and pupal period is 2 to 6 days.

3. **Brown plant hopper** (*Nilaparvatha lugens Stal*)

In recent years brown plant hoppers has become serious pest of rice in the states of Andhra Pradesh, Kerala, Orissa, Madhya Pradesh, Tamilnadu & West Bengal. Plant hoppers damage the plants by sucking the sap and by plugging xylem and phloem with their feeding sheath and pieces of tissue pushed into these vessels during exploratory feeding. Plant hopper infestation during the early stages of plant growth reduces the plant height, general vigour of the plant and the infested plant turns yellow and dries

up. A later stage, the crop dries up in patches popularly called "hopper burn". The hopper burn mostly occur at the flowering stage. The loss in yield may range from 10 to 100 per cent depending upon the extent of infestation and stage of the crop when hopper burn occurs.

Control

Insecticidal application should be made as soon as 3-5 nymphs or adults of brown plant hopper are seen per hill at vegetative stage or 20-25 nymphs or adults in the post flowering stage of the crop. Carbofuran, phorate or carbaryl+lindane granules @ 1 to 1.25 kg. a.i./ha were found effective. In late stage of infestation by brown plant hopper BHC 10% dust will be very effective.

4. **Rice bugs** (*Leptocorisa acuta*)

Rice bugs are found in almost all the rice growing areas. The nymphs and adults suck the developing grains which become chaffy. These are also called "Gondhi" bugs due to their bad smell. A female bug lays on an average 100 eggs in rows. Eggs are oval in shape and incubation period is from 5 to 8 days. Besides the adults, greenish slender nymphs also damage plants. Usually epidemic occurs during the months of September-October.

5. **Swarming caterpillar** (*Spodoptera mauritia*)

It is a sporadic but serious pest of paddy. The adult is a grey brown medium-sized moth. The female lays eggs in cluster on the leaves of the paddy plant and incubation period is 5 to 7 days. The grown up caterpillar is pale green or yellowish with dull reddish and yellowish stripes across the body. The caterpillars scrape green matters from the leaf tips and they rest within the rolled edges of tender shoots. They pupate in damp or moist soil. The colour of the pupa is dark brown and adults emerge from the pupa in about 10 to 12 days. It takes 30 to 41 days to complete the life cycle.

6. **Rice Caseworm** (*Nymphula depunctalis*)

In low lying areas Rice caseworm is a common pest of paddy. They generally feed on apical growing leaves vigorously. The caterpillar cut the leaves and roll them to form tubular cases and feed inside the tube. Eggs are laid by the female on the leaves. Caterpillars are green in colour. The larval period is about 14 to 18 days. Pupal period is about a week.

7. **Rice Jassids** (*Nephotettix virescens* & *N. nigropictus*)

Jassids are found in all rice growing areas in India. Both

adults and nymphs suck leaf juice from the leaves. Due to sucking, leaves become pale yellow and ultimately dry up from tip downwards. Incubation period is 3 to 5 days and nymphal period is about 18 days.

8. **Grasshoppers** (*Hieroglyphus banian*)

This is a serious pest of paddy. Both adults and nymphs eat leaves. The female lays eggs in the soil. One female generally lays 100-150 eggs in its life time.

Control measures

(1) At seedling stage, before transplanting, the seedlings are rinsed in 0.05% Thiodan or 0.05% Nuvan or Folithion or Ekalux.

(2) Sprays with 0.05% Ekalux or Thiodan or Folithion can control all paddy pests except paddy stem borer and gall midge.

(3) For the control of gall midge and stem borer Thimet granule or Sevidol granule or Ekalux granule are applied.

STORED GRAIN PESTS

The most important insect pests of stored paddy and rice are rice weevil [*Sitophilus* (=*Calandra*) *oryzae*], Paddy grain moth (*Sitotryga cerealella*), Lesser grain borer (*Rhizopertha dominica*), Red flour beetle (*Tribolium castaneum*), rice moth (*Corcyra cephalanica*) and saw toothed beetle (*Oryzaephilus surinamensis*). During rainy weather mites also attack the grain.

Stored grain pests are very small and they multiply very quickly. Due to the damage caused by these pests 5% of the total product is lost.

A short description of various stored grain pests are given below:

1. **Rice weevil** [*Sitophilus* (=*Calandra*) *oryzae*]

The rice weevil attacks rice, wheat, maize, jower, bazra, barley, etc. It is small, reddish brown to dark brown in colour with four light reddish to yellowish spots on the back. It has functional wings and it is about 2-4 mm long with a snout (proboscis). The adult may live 3-5 months and lays about 300-400 eggs. The rice borer uses its snout to bore the grain in order to reach the endosperm, and to make a small cavity within the grain. Inside this cavity it lays an egg. The entrance of the cavity is then closed with a gelatinous cap which has a protective function. The egg hatches in 3-6 days and a small fleshy, legless grub is formed which begins to feed on the endosperm of the grain. The larva then gives rise to the pupa. The pupal stage may persist from a few

days to several weeks depending on the environmental conditions. From the pupa adult weevil is formed. When the weevil attains maturity it emerges from the grain. During favourable conditions, the time taken by a weevil to reach the adult stage from the egg is about 4 weeks. As the weevil passes the developmental stage within the grain they are protected from the predators and sudden environmental changes. It takes about one month to complete its life cycle at 70% humidity and 28 C.

Rice weevil is a serious pest of tropical and subtropical regions. In colder countries the rice weevil cannot survive. As the rice weevils can fly it can attack the grains before harvesting causing serious damages.

Rice weevil damages grains in both larval and adult stages, causing great economic losses. In developing stage the insect lives within the grain and feeds on the endosperm, as a result the infected grain becomes almost empty. The adult weevils are also capable of eating the endosperm by boring the grain with its long, hard snout. Thus, they can cause immense losses in an infected store house within a few months.

The size and number of weevil per grain depend on the size of the grain. In a small grain there may be only one small weevil, whereas in a large grain, like maize, there may be several comparatively larger weevils.

Control measures—Weevils can be controlled by various means, such as: (a) *Drying of food grains*—If the water content of the seed is below 9% then weevils cannot lay their eggs within such grains. So the seeds must be properly dried. Drying can be done by keeping the grains in sunlight or by a grain-drier.

(b) *Fumigation*—Fumigation is done for rapid destruction of insects and other pests in a bulk of foodstaff. Certain chemicals are used for this purpose. These chemicals are known as fumigants. The aim of this process is to fumigate the grains evenly and in shortest possible time. Some of the fumigants are Carbon tetrachloride (C.T.), Ethylene dibromide, Ethylene dichloride (E.D.), etc. Usually a mixture of carbon tetrachloride and ethylene dichloride in the ratio 1 : 3 is used as fumigants in air tight store-houses. The effectiveness of a fumigant depends on the amount of its absorption by the seeds. If absorption is too high then care must be taken to remove all traces of fumigant from the grains by "airing", otherwise the grains may be poisonous. Fumigation should be done by specially trained persons.

(c) In non-airtight store-houses fumigation cannot be done. In such cases contact insecticides are used. Naturally occurring pyrethrin (obtained from *Pyrethrum* flowers) and Malathion can be used for this purpose. Usually insecticide is sprayed in godowns before keeping the grains and also on stacks of bagged foodstaff.

(d) Rice is sometimes treated with very small quantities of nut oil or castor oil, etc. to prevent infection and deterioration during storage.

(e) For transporting grains polythene bags should be used. These bags are light, air tight and are not easily infested by pests.

(f) The grains should be stored in such places where moisture and air cannot enter easily. The store houses previously used in villages are easily infested by pests but a low-cost storing house, known as 'pusa bin' has been prepared for healthy storage of grains. This is just like ordinary store houses except that, it is covered on all sides and at the base and at the top by thick polythene sheets. Besides this, scientifically prepared brick buildings are good for storing grains.

2. **Lesser Grain Borer** (*Rhizopertha dominica*)

This is also called borer beetle. Both the adults and the larvae feed on rice, wheat, maize, various millets and pulses. They also damage flour, semolina, biscuits and other dried vegetables.

The dark brown beetle is about 3 mm. long and 0.8 mm. wide. The female lays eggs in the loose grain or gunny bags or in the cracks and crevices of the stores. One female lays 300 to 450 eggs in its life time and incubation period is about 6 days. The larvae just after hatching bore into the grains and feed inside. Larval period is about 30 days. Pupation takes place inside the grain or grain dust. Adult may live upto 5-6 months. The grubs and the adult beetle completely empty the kernel and after the attack only the bran coat remains. It breeds usually in tropical and subtropical climates, but can also survive and breed in temperate climates. For controlling, high dosages of fumigant can be used.

3. **Paddy Grain Moth** (*Sitotryga cerealella*)

It is a serious pest of whole grains of rice, jowar, maize, and wheat. The moth is brown in colour and the adults do not damage the grain. The females lay eggs on the grain not only in the godown but also in the field. Incubation period is 4 to 6 days and whitish stout caterpillars hatch out and bore into the grain. It takes 16-20 days to pupate inside the grain and makes the grains

hollow. Pupal period is about a week. The entire life cycle is usually completed in about 32 days. Early harvesting can minimise the damage caused by this insect as the soft bodied moths cannot make their way below the surface of the binned grains.

4. **Rice Moth** (*Corcyra cephalanica*)

It is a serious pest of rice and jowar and broken pulses. It also breeds on many of the dried fruits. The moth is pale and grayish brown in colour. The female lay white and globular eggs on the food material. The creamy white larvae make a shelter within the heap of food material in which they live and feed.

5. **Khapra beetle** (*Trogoderma granaria*)

It is a serious pest of wheat and it also attacks jowar, rice, gram, maize and pulses. The adult beetle is red, brown or black in colour and are found throughout the world. Only the larval stage is harmful. Thde larva is brownish white in colour. The larva have been reported to live as long as 4 years, but average larval period is 18 to 25 days.

Control measures—A routine procedure of pest control is followed in India in Government managed warehouses where paddy is stored in bulk or in bags. BHC, Ethylene dichloride and Carbon tetrachloride are some of the chemicals used for control. Empty godown should be sprayed with 0.5% Malathion. When entire stock is infected with grain pests, fumigation should be done with Ethylene dichloride and Carbon tetrachloride mixture (EDCT) or fumigated with Aluminium posphide tablet which is very effective against the grain pests.

An indigenous insecticide—Rhizomes of *Acorus calamus* (Sweet flag) mixed with the grain at the rate of one kg. per 100 kg. of grain gives better control of *Rhizopertha, Sitophilus* and *Tribolium* than BHC or Gammexane.

6

A KNOWLEDGE ABOUT THE IMPORTANT WILD ANIMALS. METHODS OF CONSERVATION OF TIGER AND RHINOCEROS

With the increase in human population the forest areas have been much reduced and with this the number of wild life gradually decreases. Wild life includes the flora and fauna of forests. Many wild animals have become extinct being unable to adapt in the changed environmental conditions and some became extinct due to man's injudicious practice of killing them. Those animals which are hunted by man for various reasons, such as, for obtaining skin, horn, tusk, flesh or for the fun of hunting, etc. are called game animals.

By killing wild animals indiscriminately man disturbs nature's balance of the ecosystem. In the last 200 years about one hundred species of animals have become extinct and many more are going to be extinct. A list of the few animals which have become extinct in recent past are given below:

Name	*Place where they lived*	*Approximate year of extinction*
1. Dodo (a bird)	Mauritius & Reunion Island	— 1700
2. Auks (a bird)	Iceland and Hebrides	— 1884
3. Passenger Pigeon	United States	— 1914
4. Quagga	Africa	— 1882
5. Stealer's Sea Cow	Cooper Island and Boring Island	— 1775
6. Mountain Quail	India	— 1876
7. Pink headed Duck	India	— 1930
8. Jordon's Courser	Andhra Pradesh, India	— 1900

Besides these, there are many animals which are on the way of extinction. These include Tuatara of Newzealand, Bald Eagle and Hopping Crane of North America, Giant Panda of China, Crested Ibis of Japan, White Rhinoceros of Africa, Walrus and Polar Bear of North Pole, etc.

Indian animals which are on the verge of extinction are: Golden Cat, Marbled Cat, Kashmir stag, Musk deer, Black duck,

Swamp deer, Nilgiri Thar, Indian wild ass, Indian lion, Indian wolf, Clouded Leopard, Snow Leopard, Tiger, Wild Buffalo, Rhinoceros, Pigmy Hog, Crocodile, Gharials, Lion tailed Macaque, Snow Loris, Rhesus Monkey, Nilgiri Langur, White winged Wood Duck, Great Indian Hornbill, Large Falcon, etc. From this list it is now evident that the preservation of those species which are already approaching extinction, is the most urgent problem facing zoologists and naturalists everywhere today. This is also true in case of Indian wild life.

Although any rare species may deserve protection from the scientific point of view, the objects of present day wild life preservation is to keep the population of wild life directly useful to even at their optimum.

Beneficial role of wild life

1. **Recreation**—Man gets thrilling enjoyment in seeing the fearsome tiger, the majestic lion, the lordly elephant, the beautiful deer and the charming peafowl. The various sounds produced by wild animals, particularly the songs of birds are a source of recreation.

2. **Scientific research**—The ever increasing emphasis which is being laid on scientific research in the present age has made the preservation of wild life essential. Monkeys and rodents are used as laboratory animals in medical and vaterinary researches.

3. **Economic benefits**—(a) *Wild life as trade*—Several products derived from wlid animals, such as, fur, meat, horns, ivory, musk, bones, feather, etc. are important articles of commerce. Several species of Indian wild life, such as, *Rhinoceros*, Rhesus monkey whose price is too high in other lands may be a good source for foreign exchange.

(b) *Balance of nature*—Each species of wild life is economically important in its own way as it helps to maintain the balance of nature.

(c) *Flower pollination*—Several species of birds are very effective agents in cross pollination of flowers.

(d) *Improvement of domestic breeds*—Wild animals can also be used to invigorate our own domestic breeds.

(e) *Attraction to tourists*—Wild life of India helps to earn a handsome amount of foreign exchange by being a great attraction to tourists.

4. **Scavenging and manuring**—Several species of wild animals are useful agents in scavenging the country side and forests. By burrowing, some wild animals also help to increase the fertility of soil.

With the rapid growth of the human population some animals are gradually decreasing in number. It is, therefore, felt that proper preservation methods must be undertaken to save such animals.

Measures undertaken for preservation—One of the most important steps towards wild life preservation in India during recent years is the setting up of Indian Board for wild life (1952) and State Boards for wild life.

The Indian forest Act, Arms Act, and Wild Birds and Animal protection Act are the legislations which help wild life protection in India.

Wild life sanctuaries and National Parks—Among the measures adapted for the protection of wild life in India, sanctuaries and national parks are very important. In these places animals can live without fear and also get favourable condition for breeding and for getting sufficient food.

Important Sanctuaries in India (Fig. 80)

1. **Kaziranga Sanctuary**—Kaziranga Sanctuary is situated 90 km. away from Jorhat, Assam. Its area is about 422 sq. kilometres. The great attraction of this sanctuary is the Indian Rhinoceros. There are about 800 such rhinoceros in this sanctuary. Besides rhinoceros, there are swamp deer, tigers, elephants, wild buffoloes and birds of various types.

2. **Jaldapara Sanctuary**—This is situated in the northern part of West Bengal. Its area is about 100 sq. km. although the main attraction of Jaldapara is rhinoceros, various other wild animals are also present here.

3. **Dachigam Sanctuary**—Darhigam sanctuary is situated in the northern part of Kashmir, where there are more than 200 Kashmir stags which form the main attraction of the sanctuary. Besides these, snow leopard, bear, musk deer are also reared in this sanctuary.

4. **Gir Sanctuary**—This is the largest sanctuary in India and is situated in Gujarat at a distance of 380 km. from Ahmadabad. Its area is 1280 sq. kilometres. This is meant for the preservation of lions in their natural habitat. There are more than 300 lions in this sanctuary.

5. **Bandipur Sanctuary**—Bandipur sanctuary is situated in the southern part of Karnatak and its area is about 57 sq. kilometres. The most important wild animal are the Bison, wild elephant, etc.

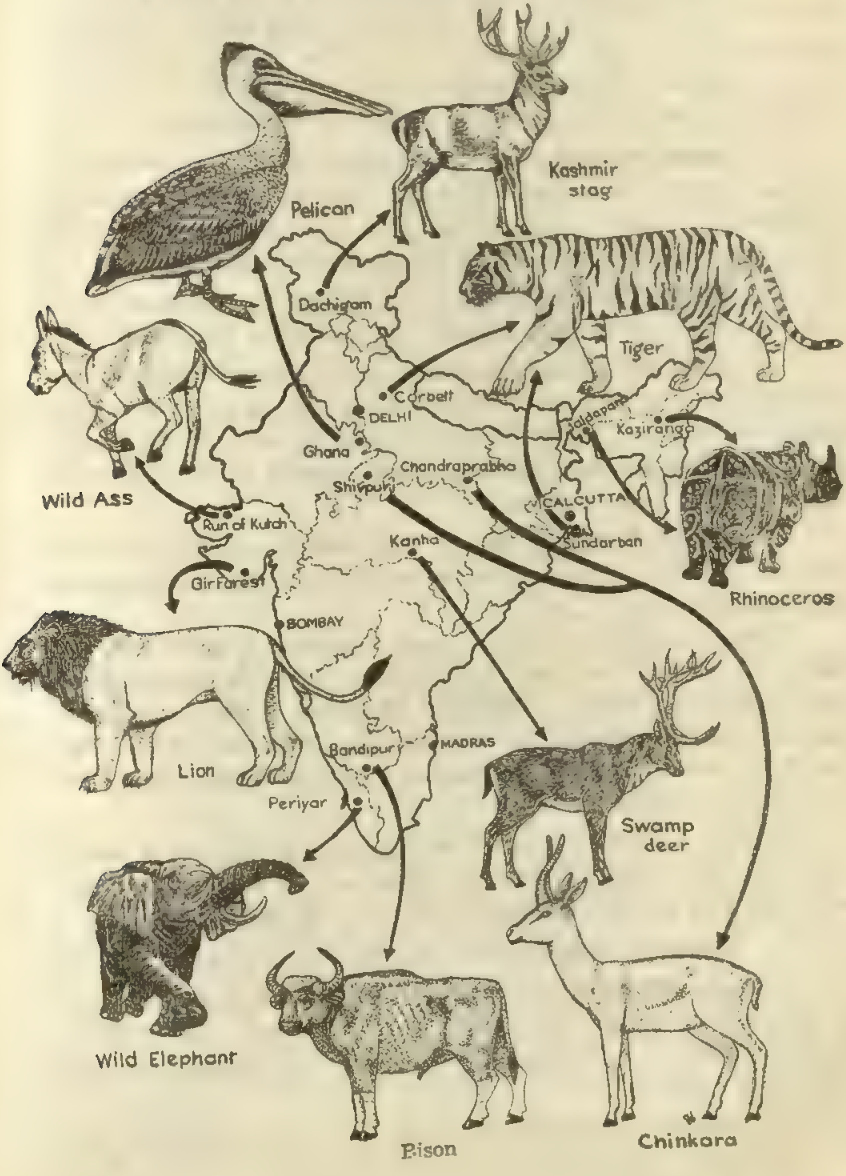


Fig. 80. Map of India showing location of important wild life sanctuaries and the major animal of each sanctuary.

6. **Periyar Sanctuary**—Periyar sanctuary is situated in Kerala and its area is about 594 sq. kilometres and is famous for the large numbers of wild elephants. It is also noted for its natural beauty.

7. **Corbett National Park**—It is situated in the Dun Valley in the foot-hills of Himalayas. This has been named after Jim Corbett, the famous naturalist and hunter. The area of this park is 320 sq. km. Although the main attraction of this park is tiger; elephants, leopards, bears, deers and other animals are found here.

8. **Kanha National Park**—It is situated in Madhya Pradesh at a distance of 180 km. from Jabbalpur. The most important animal found here is swamp deer. Kanha is a very beautiful area where there are excellent arrangements for seeing wild animals.

9. **Shivpuri National Park**—It is situated near Gwalior. There are good numbers of India Gazella or Chinkara is this forest.

10. **Keoladeo Ghana Sanctuary**—It is situated at Bharatpur (Rajasthan) at a distance of 155 km. from Delhi and 50 km. from Agra. It is one of the best bird sanctuaries in India. Many beautiful birds are found here and many birds migrate to this area from different parts of the country.

11. **Manas Sanctuary** lies in the foothills of Himalayas in Assam. Various animals including birds and fishes are found in this sanctuary.

There are other sanctuaries where important wild animals are kept. These are Chandraprabha Sanctuary (in U.P.), Ranganthitoo Bird Sanctuary (Mysore), Mudumalai Sanctuary (adjacent to Bandipur Sanctuary), Vedanthangal bird sanctuary (Madras) and Chandak Sanctuary which includes the Nandan Kanan Biological Park near Bhubaneswar (Orissa).

In West Bengal there are 8 sanctuaries (Fig. 81) out of which Jaldapara and Sajnakhali are very important. Following rare animals are kept on different sanctuaries, as given below :

(a) **Jaldapara Sanctuary** (93 sq. km) in Jaldapara district.

Animals preserved—1. Rhinoceros, 2. Elephant, 3. Tiger, 4. Sambar, 5. Swamp deer, 6. Pea fowl, 7. Python, 8. King cobra. 9. Wild buffalo, 10. Wild pig, 11. Hog deer, 12. Indian Bison and 13. Jungli fowl.

(b) **Garumara Sanctuary** (8.7 sq. km) in Jalpaiguri district.

Animals preserved—1. Tiger, 2. Sambar, 3. Python and 4. Jungli fowl.

(c) **Chapramara Sanctuary** (8.8 sq. km) in Jalpaiguri district. *Animal preserved*—1. Elephant, 2. Samber.

(d) **Cenchal Sanctuary** (39 sq. km) in Darjeeling district. *Animal preserved*—1. Barking deer, 2. Wild dog, 3. Wild pig, 4. Goral, 5. Himalayan bear.

Fig. 81. Map of West Bengal showing the location of different wild life sanctuaries.

(e) **Mahanadi Sanctuary** (127.7 sq. km) in Darjeeling district. *Animal preserved*—1. Tiger, 2. Spotted deer, 3. Jungli fowl, 4. Sambar, 5. Leopard, 6. Wild pig, 7. Indian Bison, 8. Pea fowl, 9. Barking deer and 10. Himalayan Black bear.

(f) **Sajnakhali Sanctuary** (352.8 sq. km) in 24 Parganas. *Animals preserved*—1. Pelican, 2. Egret, 3. Heron, 4. Stork, 4. Ibis, 6. Wild pig, 7. King cobra, 8. Spotted deer, 4. Crocodile and 10. Tiger.

(g) **Holiday Island** (6 sq. km) in 24 Parganas. *Animals preserved*—1. Crocodile, 2. Wild pig, 3. Spotted deer, 4. King cobra, 5. Tiger.

(h) **Lothian Island** (38 sq. km) in 24 Parganas.

Animals preserved—1. Crocodile.

Short descriptions of few important wild animals (reptiles, birds and mammals) are given below.

Reptiles

Crocodile—Various kinds of crocodiles are found throughout the world and they belong to there families, namely, Alligatoridae, Crocodildiae and Gavialidae. In America and China allegators are found, whereas in India two species belonging to Crocodildiae and one species belonging to Gavialidae are found. In estuaries *Crocodilus porosus* and in fresh water *C. palustris* are found. *Gavialis* (Gavialidae), commonly known as gharials are found in rivers of India. Gharials are on the verge of extinction and they are now preserved in Nandankanan, Cuttack, Tikarpara of Orissa.

Birds—Birds are beneficial to man in various ways. Crows and vultures feed on garbage and act as scavengers. Owl, sparrow, eagle, etc. feed on pests and are thus helpful to man. The number of these birds are also on the decrease. A description of a few wild birds are given here.

(a) **Crane**—This long necked bird is found in the paddy fields and marshlands of Northern India. Their scientific name is *Grus antigone* and they are about 5 ft. high and possess a red head with lower part of the neck being bluish.

(b) **Peafowl**—Peafowl is one of the most attractive bird and is declared as national bird of India. There are two species of peafowl namely, *Pavo cristotus* (Indian) and *P. muticus* (Burmese). Indian Peafowl is found all over India from the plains upto the height of 1700-2000 metres and in Nepal and Sri Lanka. Burmese peafowl is found in Burma, Assam and Bangladesh. Peafowls are carnivorous.

(c) **Cormorant** is a webbed footed aquatic bird. It has a black body with a white neck. Various species of cormorant (*Phalacrocorax sp.*) are found in India. They feed on fish and their tails and feathers are modified for aqutic life.

(d) **Large Indian Bustard** is a large bird weighing 15-20 kg. and is found in the desert areas of Gujarat and Rajasthan. This bird (*Choriotis nigriceps*) can run and fly.

Mammals

(a) **Leopard**—The hunting Leopard (*Acinonyx jubatus venaticus*) was once found throughout India. But it became

extinct from India by about 1952; now it is found in dry zones of South East Asia and in Africa. Hunting leopards are the fastest terrestrial animals. They are about 2 metres long and about 0.75 metre high. They feed on deer, antelope, etc.

(b) **Lion**—Indian lion (*Panthera leo persica*) once found abundantly in the forests of western, central and northern India, was on the verge of extinction by 1913, when only few lions were left in the Kathiwar peninsula. They are now preserved in the Gir sanctuary which is the last strong-hold of Indian lions. There are over 300 lions in Gir forest now. African lion (*Panthera leo leo*) is found in the Serengetti sanctuary of Tanzania. There is about 800 african lions in the sanctuary.

Mature male lions possess mane. The mane of Indian lion is thin and short, while the African lion has thick and long mane. Indian lions have a maximum length of about 3 metre and African one is about 30 cm. longer. Lions live in small groups in the thickets of trees or hillocks or on the banks of river spread over the jungles. They kill animals, like, wild pig, bulls, buffaloes, deer, fox, etc.

(c) **Nilgiri Langur** (*Pesbitis johnii*) is found in the hills of Southern India. It has a blackish brown body and a yellowish brown head. The length of its head and body is about 0.75 metre and the tail is also 0.75 metre long. These monkeys live in a group of 5-10 individuals in the dense evergreen forests at a height from 1000-2000 metres. They are vegetarian. Some tribes kill these langurs for their soft, beautiful fur and supposed medicinal value of their flesh, blood and organs. For this their number has decreased considerably.

(d) **Musk deer** (*Moschus moschiferous*) is found in Central and North Eastern Asia. In India it is found in Kashmir, Himachal Pradesh, U.P. and Sikkim. It is very small and in between deer and the antelopes in its body structure. It lacks horns, the male possesses large canine teeth and musk gland, situated beneath the skin of the abdomen. Musk is produced from this gland. Musk deer has a specially developed mobile feet. The number of this deer has decreased considerably due to indiscriminate killing by man.

(e) **Chital or spotted deer** (*Axis axis*)—It is found in the forests with good grazing ground and plenty water almost throughout India particularly in the foot hills of the Himalayas. It is the most beautiful of all deers. Its brownish body has profuse white

spots. They move in groups of 10-30 and feed in the morning and evening. The time of shedding of antlers of stags varies. They are about 0.75 metre high.

(f) **Elephant** (*Elephas maximus*)—It is found in forests of India, Sri Lanka, Bangladesh and in countries of S.E. Asia. They are about 3 metres high. Only the males have large tusks. Indian elephant differs from African ones being smaller, does not possess enormous ears, hollow back, 3 nails in the hind legs (it has 4 nails in the hind legs) and two lips (it has only 1 lip). Usually they move in groups of 5-60 or more. They feed in the morning, evening and early part of the night.

Rhinos

In ancient time rhinos were found in Asia, Europe, Africa and N. America but their number decreased considerably in recent time. Today there are only five species of *Rhinos* in the whole world. In Africa there are two species, namely, *Diceros bicornis* (black rhino) and *Diceros simus* (white rhino). In South East

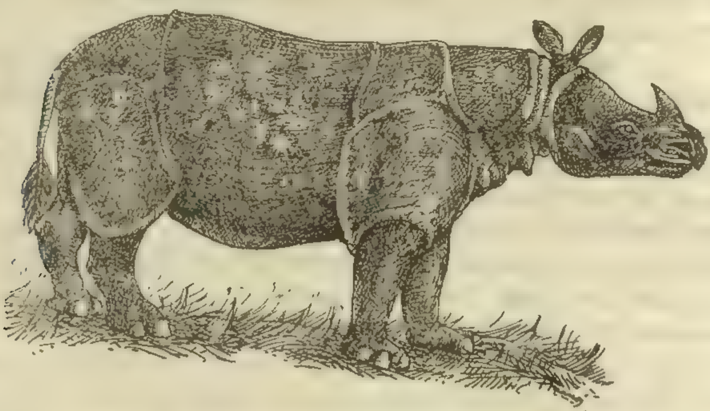


Fig. 82. One horned Indian Rhino-*Rhinoceros unicornis.*

Asia there are three species. In Malayan Peninsula and Java small one horned rhinos belonging to the species *Rhinoceros sondaicus* are found. In Sumatra and some parts Burma, Asiatic two-horned rhinos, namely, *Rhinoceros sumatransis* can be found. The great one horned Indian rhinoceros belongs to the species *Rhinoceros unicornis R. sondaicus* was found in India in nineteenth century but it became extinct from India (Assam & Bengal) by 1874. Similarly *R. sumatransis* became extinct from Assam, Bhutan and North Bengal about 90 years ago.

Several centuries ago the Indian rhinos are known to have been common and widespread throughout Northern and North Western India and neighbouring countries. In 1904 it was estimated that about a dozen individuals remained in the Kaziranga district of Assam and the survivals in Bengal were probably fewer than that.

Indian Rhinos—The great one horned Rhinoceros—*Rhinoceros unicornis* (Fig. 82) are found in Bengal and Assam. Usually they roam singly in grasslands. They make a grunting sound. They excrete always at a particular place. The population of the great Indian one horned Rhino in 1964 was as follows : Bengal 65, Assam 375 (according to E.P. GEE). But their number has increased considerably and at Kaziranga alone there are more than 800 rhinos now.

General size of one horned Rhino—The great Indian one horned rhinoceros is the largest of three Asiatic species. Full grown specimens may attain a length of at least 4.27 metre ; a shoulder height of 1.89 metre ; and a weight of 2.03 metric tons. The length of the horn may reach 60 cm. The horn, which is quite different from the horns found in any other animals consists of a compact mass of horny fibres representing modified hairs growing out from the skin of the snout. It is short and thick at the base and usually quite blunt. In female rhinos the horn is comparatively sharper than that of the males.

Cause of gradual decrease in number of Rhinos—1. Rhinos are commercially valuable creatures. Almost every part of the animal could be sold including meat. The really valuable part of the animal, however, is the horn. Throughout the east and particularly in China, it was in great demand on account of religious purpose. Even in recent times the price of horn is Rs. 2525 per 500 gm.

2. In the nineteen century killing of rhinos was an interesting game for hunters.

3. It is a slow and clumsy animal devoid of any defensive tactics even in the face of greatest danger. On account of their habits the rhinos are completely helpless in the hands of its enemies.

4. Another cause of reduction in the population was due to disease (such as, Anthrax) believed to have been contracted from the domestic cattle and buflaloes belonging to the native population.

5. It is a slow breeder, about six years is said to be the interval between two consecutive births. Each time it gives birth to a single young. Gestation period is about 1½ years.

6. Agriculture played an important role for the decrease rhino population. In the last century the Brahmaputra valley in Assam was mostly covered with thick grass and jungle. With the development of agriculture in the plains as also in the hilly regions, jungle areas have decreased considerably leading to the decrease in the number of rhinos.

Preservation—There was a sudden realization at the beginning of this century that the number of great Indian one-horned rhinoceros was very few. This inspired the authorities to take desperate measures to save the species. The animal was accorded absolute protection in a number of areas, like Kaziranga, Jaldapara, etc.

For conservation of Rhinos certain measures are taken, some of these are discussed here. As they love marshy lands having high grasses they are provided with such conditions. As the rhinos feed on grasses there should be an abundant supply of grasses. They may be attacked by anthrax disease, for the prevention of which adequate measures are taken. They are given anthrax vaccines. As the disease comes from domestic cattles, etc. such animals are prevented from entering within the preservation area. The diseased rhinos are usually removed to a separate place.

Tiger

There are about nine subspecies of tiger (*Panthera tigris*) in the whole world. In India *Panthera tigris* is found. It is a very graceful and an attractive animal. Tiger (Fig. 83) can be found

Fig. 83. A Royal Bengal Tiger.

in various places of Asia. It can adapt under varying conditions. The tiger can live in dry thorny forests, deciduous forests, evergreen forests, in grass-lands and also in mangrove forests. It can

also withstand a wide range of temperature variations, such as, warm conditions of Sundarbans to cold condition of Nepal. It can swim in water and can run very fast. Tiger attains sexual maturity at the age of 3-4 years and can live upto 20 years. The tigress gives birth to young ones in dense forest or caves. When the cubs become nearly 1½ years old, they begin to hunt on their own. Usually they kill the prey during morning and evening. They usually attack from behind with lightning speed. According to E.P. Gee, an authority on wild life only 3-4 tigers per thousand are man-eaters.

With the very increase in human population, forest trees have been ruthlessly cut down for extension of cultivated areas. As a result, the number of forest animals, like, goats, deer and other animals has gradually decreased and there is scarcity of food for the tigers. So they were compelled to come to or near the areas of human habitats. The farmers killed a large number of tigers putting poison as a bait. Hunters also killed many tigers especially for their beautiful skin.

Due to these causes the number of tigers came down considerably. There were about 40,000 tigers in India not very long ago but in 1972 number of tigers was found to be only 1827 (73 in West Bengal). Under the Tiger Project of the Government of India, tiger has been declared as national animal of India. It is now declared as a protected animal and various measures are now being taken for their preservation.

As the tiger brings the killed animal near water and then eats its flesh, so it is necessary to have abundant water sources where tigers are to be preserved. There should also be adequate hiding places for the tigers. The tiger loves the flesh of deer, cattle, pig, goat, etc., so these animals should be present in the tiger forest. As the tigress gives birth to young ones only in caves or dense forest, there should be some such places in the forest. The area of the forest should be in accordance to the number of tigers to be kept there. Laws are formulated to protect tigers from hunters. In West Bengal by Wild Life Conservation Act (1959) and Indian Wild Life Conservation Acts (1972, 1974) tiger killing is prohibited. A tiger project was taken in 1972 prohibiting killing of tigers for 6 years. The World Wild Life Fund has sanctioned a grant of 6 crores of rupees for tiger project. The tiger project in India

was started on 1st April, 1973. Under this scheme nine Tiger Reserve Centres were set up, a list of which are given below :

Tiger	Reserve Centre	Province	No. of tigers
1.	Manas	Assam	31
2.	Sundarban	West Bengal	73
3.	Palaumo	Bihar	22
4.	Simlipal	Orissa	50
5.	Corbett National Park	U.P.	44
6.	Kanha	M.P.	43
7.	Ranthombor	Rajasthan	14
8.	Melghat	Maharastra	27
9.	Bandipur	Karnatak	10

The numbers of tigers in these reserve forest have already increased considerably.

PHYSIOLOGY

1

FOOD AND METABOLISM

(Biochemical composition of common Indian foods such as Rice, Wheat, Maize, Milk, Egg, Fish, Meat, Pulses and Fruits etc. Digestion of food in the Alimentary Canal. Absorption of foods and metabolism.)

FOOD

Life can not exist without food. Food is the fuel or energy for every living organism. The food is assimilated in the body and is utilized for the growth, reproduction and maintenance of life. Animals can not manufacture their foods like plants. An animal satisfied its requirements of foods by and through the *natural selection*. Man has a number of food stuffs both from plant and animal to make up his adequate diet. Dietary habits different regions of the world is influenced mainly by the local availability of foods. Insufficiency of food is known as malnutrition which affects both growth and normal health. Thus an adequate diet is absolutely necessary. The principal constituents of human diet may be classified into the following six items:

(1) Carbohydrates, (2) Proteins, (3) Fats, (4) Vitamins, (5) Minerals and (6) Water. The first three items are used for energy production, growth and maintenance of tissues and the last three are mainly for chemical mechanisms, i.e., utilization of energy, synthesis of necessary metabolites, viz., hormones, enzymes etc. Vitamins and minerals do not supply energy. Minerals are essential to form body structures like bones and teeth.

Carbohydrate, Protein and Fat are sometimes called "Proximate principles". These are oxidised or burnt in the body to supply the energy for the various activities of the life. A well-balanced diet should contain all these factors in correct proportions and in adequate amounts.

Carbohydrate—Carbohydrates form the main source of energy to the body. As a cheap source of energy, carbohydrates form the bulk of the Indian diet and these include starch, cane sugar, glucose and milk sugar. This is usually supplied from rice, wheat, potato and milk lactose. Carbohydrates are classified as poly-

saccharide (starch), disaccharide (cane sugar) and monosaccharide (glucose, galactose).

Biochemically carbohydrate is generally defined as a neutral compound and consists of carbon, hydrogen and oxygen. Chemically carbohydrate can be defined as the aldehyde and ketone derivatives of higher polyhydric alcohol.

Human body utilises carbohydrate in the form of monosaccharide i.e., glucose.

Functional importance of carbohydrate is the following :—

(1) It is a readily available fuel of the body.

(2) It forms the structural material of the tissue.

(3) It acts as an important storage of food material (i.e. muscle glycogen).

(4) It plays a key role in the metabolism of amino acids and fatty acids in the body.

Protein—Proteins are the chief substances in the body. They form the important constituents of muscles, tissues and vital fluids like plasma protein of blood. Protein supplies the building material of the body and helps in wear and tear of tissues and it is known as *"body building food"*.

Animal foods such as meat, fish, egg and milk are rich in protein. Among the vegetable foods, pulses and nuts are the chief sources of protein. Soyabean is unique and it contains over 40 per cent protein. Rice and wheat are relatively poor sources of proteins. Rice contains less protein than wheat but the protein of rice is of better quality. Leafy and root vegetables and fruits are very poor sources of protein.

Protein consists of not only hydrogen, carbon and oxygen but also it includes nitrogen, sulphur and phosphorous ; 16% of protein is nitrogen. Amino acid is produced when protein is hydrolysed. Amino acid consists of amino (—NH_2) and carboxylic (—COOH) groups in their structures. In protein, the amino acids remain as a peptide bond i.e.,—NH_2 group of one amino acid is attached with-COOH group of other amino acid. In this way they form a chain of amino acids. When two amino acids are present it is called dipeptide ; and more than two amino acids constitute polypeptide. Protein may be classified into three forms i.e., *simple* (albumin, globulin), *conjugated* (chromo—, phospho—and nucleoproteins) and *derived* proteins (which is not found in the nature

and is usually derived as products of hydrolysis of native protein molecules i.e., the stages are : protein $\rightarrow$ protean $\rightarrow$ metaprotein $\rightarrow$ proteose $\rightarrow$ peptone $\rightarrow$ peptides $\rightarrow$ amino acids). Haemoglobin is a *chromo-protein* where globin remains united with an iron containing pigment, haem. DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) in combination with protein form the *Nucleio-proteins.* These are *conjugated proteins.*

Human body utilizes protein in the form of amino acids after digestion in the alimentary canal and then constitutes the various protein by their metabolism in liver and various tissues.

Biological value of protein—In addition to the quantity of protein, the nutritional quality of the protein is very much important to judge the protein value of a diet. Proteins differ in their nutritive values due to an account of differences in the amino acid composition. Amino acids are the "bricks" in which the tissue protein is built and replaced. There are about twenty amino acids commonly found in the diet. About 8 amino acids cannot be synthesized by the body and it should be supplied through the diet. These amino acids are therefore called "essential amino acids". These essential amino acids thus determine the quality of the protein. The proteins of animal foods such as milk, fish, meat, egg, etc. contain the essential amino acids and these foods are considered to contain good quality of proteins. The cereal proteins are poor in the amino acid, lysine ; and pulse proteins are poor in methionine although these are rich in lysine. Such proteins individually are therefore incomplete proteins. The adequate combination of these proteins (i.e., cereals and pulses) have a mutual supplimentary effect.

The nutritive value of a protein depends not only on its *essential amino acids but also on its digestibility power.*

The amounts of nitrogen in the diet as protein and the excreta of adult animals are measured and the percentage of nitrogen retained by the body after absorption from the diet is calculated. The value thus obtained is expressed as the "biological value" of the protein.

Animal proteins are of higher biological value than vegetable proteins.

The quality of the protein can also be judged by measuring the *gain in weight* of young animals per unit weight of protein consumed. This value is known as the "protein efficiency ratio".

Nutritive value of the Proteins of some food stuffs.

Food stuffs	Biological value	Protein efficiency ratio
Rice	68	2.2
Wheat	66	1.5
Bengal gram	68	1.7
Egg	94	3.9
Milk	84	3.1
Meat	74	2.3
Fish	76	3.5

According to the modern concept the daily need of the proteins of an adult is one gram per kilogram of body weight. But growing children need more. Similarly woman needs greater protein during pregnancy and lactation. The above table shows that *egg* is the only protein where biological value and protein efficiency ratio are highest in comparison to other food stuffs.

Function of protein is to maintain growth of the organisms and reparing of tissues. Besides these, protein is utilized to form various hormones and enzymes. Starvation causes break down of protein of the body.

Fat or Lipid—Like protein, fat is necessary ingredient in the diet. The chief sources of fat are animal fats such as ghee, butter; and the plant fats are coconut oil, vanaspati, ground nut oil. Cereals, pulses and vegetables contain negligible amount of fats.

Fat is source of energy and it is also necessary for maintanance of normal health.

Fats are the esters of higher aliphatic acid and glycerol and these are insoluble in water but soluble in fat solvents like chloroform, ether, benzene. Due to the presence of replaceable—OH group, alcohols behave like alkalies and as such combine with acids to form salt and H_2O. This salt is known as esters. Fatty acid esters may be formed with alcohols other than glycerol, such as waxes. The fatty acid usually contains even number of carbon atoms and are straight chain derivatives. This may be represented as HOOC—F. The general formula of fatty acid is $C_n H_{2n+1}$ COOH. This may be of two types: (1) *saturated* (contains no double bond); and (2) *Unsaturated* (contains one or more double bonds or ethylene groups). *Simple lipids* are triglycerides, *compound lipids* are combined with other non fatty prosthetic groups, e.g., phospholipids, glycolipids, lipoprotein etc. *Sterols*

are not true fats but these are found free or in caster bonds with fatty acids (cholesterides). Fat metabolism influences the level of cholesterol in blood and thus causes atherosclerosis in which the blood vessels are narrowed and hardend and may cause coronary heart disease where the blood cholesterol level is increased to a very high level.

Apart from quantity of fat the *quality* of fat in the diet is also important. Some fats are essential for the body and are known as "essential fatty acids." The deficiency of these fatty acids may cause a skin disease called phrynoderma (toad skin) in which skin becomes rough and thick with horny papules. *Some fatty acids like ground nut oil* contain a high proportion of polyunsaturated fatty acids which do not increase the blood cholesterol level. On the other hand certain fats like ghee, butter, coconut oil, vanaspati, contain a high proportion of saturated fatty acids and *elevate blood cholesterol level when taken as large quantity*. Daily intake of fat should be around 10—20 per cent of the total calories in diet. If fat content in the diet is increased to more than 40 per cent of the total calories in diet there would be an increase of cholesterol level in blood. *Vigorous exercise* may cause a toleration of higher fat without much increase of blood cholesterol level.

A total of about 50 gms of fat can be safely consumed daily and at least 15 gm vegetable oils should be given daily to the adults to supply the essential fatty acids.

Vitamin—The vitamins have important functions in many of the vital processes of life. These are essential for health but these are need only in small amounts. Vitamins must be supplied from external sources, so that the specific physiological functions, vital to life, may go on normally.

Based on their solubility, vitamins are broadly divided as fat soluble (A, D, E, K) and water soluble (B complex and vitamin C) Defficiency of Vitamin may cause various diseases.

Vitamin A—Vitamin A is found in butter, ghee, whole milk, curds, egg yolk, liver etc. Vegetable foods contain carotene which is the precursor of Vitamin A. Carrots, spinach, cabbage, radish leaves, ripe fruits, mango, tomato are rich in carotene. Daily requirement is 750 mg. Vitamin A helps to *prevent night blindness*. It regenerates visual purple and prevents keratinization of epithelial tissue.

Vitamin D—It is found in liver, liver oils, egg yolk, milk, butter, ghee, etc. Vegetable sources are usually nil. It is essential for *bone development.* Daily requirement is about 200 to 400 International Units for children; and for adults, the doses are not known with certainty.

It prevents rickets and osteomalacia. It plays an important role in the absorption of calcium from the intestine. The cheapest way of obtaining this vitamin is the exposure of the body to sunlight.

Vitamin E—It is present in vegetable oil and green leaf. The quantity of daily need for human has not been established. *It prevents sterility and muscular dystrophy.*

Vitamin K—It is available in green leafy vegetables. The quantity for daily uptake is not yet known. *It is essential for blood clotting* as it forms prothrombin of blood and hence *prevents haemorrhage.*

B-Complex—There are many vitamins grouped under B-Vitamin. These are the following :—

1. **Thiamine (B_1)**—These are available in unmilled cereals, pulses and nuts (ground nut). Daily need is one milligram. *It prevents berriberi.*

2. **Riboflavin (B_2)**—Good sources of this vitamin are milk, curds, cheese, egg, liver and green leaves. The requirement is about 1.5 mg per day. It acts as a coenzyme and helps in oxidative processes in the cells. *It prevents cheilosis.*

3. **Nicotinic acid (Niacin)**—The source is whole cereals, pulses, nuts and meat. Daily requirement is about 10 mg. It helps in metabolism and acts as a coenzyme. It prevents *pellagra.*

4. **Vitamin B_6**—This vitamin exists in three forms : mutually interchangeable in the body. The source is meat, liver, vegetables and whole cereal grains. The amount of daily need has not yet been established. It acts as a coenzyme. *Anaemia has been shown to be improved by B_6.*

5. **Pantothenic acid**—It is available mostly in common foods. The human requirement for this vitamin has not been clearly defined. *It cures "burning feet" and sore tongue.*

6. **Folic acid**—It is avaialable in fresh green vegetable, liver, pulses, etc. The requirement may be about 100 mg per day. Deficiency of this vitamin results certain types of *anaemia*

especially in infants and in pregnant women. It is involved in maturation and multiplication of red cells.

7. **Vitamin B_{12}**—Only animals foods like milk, meat and liver appear to contain B_{12}. It helps in maturation of red cells and *its deficiency causes anaemia.* The requirement of daily dose is not known.

Only the important B-complex has been described which has important role in human metabolism.

Vitamin C (Ascorbic acid)—It is usually found in fresh fruits and vegetables (green leaf); orange, lemon, guava and tomato are the chief sources. *It prevents scurvy.* 30-50 mg of vitamin C is needed daily. *It is necessary for proper calcification of bones and teeth.*

Mineral Salts—Human body possesses a large number of minerals. Bones and teeth are made up mainly of calcium, magnesium and phosphorus; and iron is an important constituent of blood. Iodine is necessary for formation of thyroxine hormones. Minerals like zinc, molybdenum and manganese are either constituents or activators of some enzymes. Sodium and potassium are also necessary for the body. *Most of the common foods are the sources of these minerals. Milk is deficient in iron.* Deficiency of minerals may cause anaemia. The daily intake of calcium is 0.4 to 0.6 gm for adult. 20-40 mg of iron is necessary for a balanced diet of an adult. *Mineral supply in adequate dose is necessary for growth of the children.*

BALANCED DIET

A balanced diet contains different types of foods in such quantities and proportions that the need for calories, minerals, vitamins and other nutrients is adequately met. The proportions of fat, protein and carbohydrate are given below, which suits only for the standard man of India.*

TABLE: 1.

Kilo-Calories requirement of protein, fat and carbohydrate:

Amount of food	Kilo-Calories	Percentage of total calories
50 gm protein	$50 \times 4.1 = 205$	8.2
50 gm fat	$50 \times 9.3 = 465$	18.5
450 gm carbohydrate	$450 \times 4.1 = 1845$	73.3
Total	2515	100

* Standard man of India possesses 50 kg body weight and 163 cm height.

TABLE : 2.

Balanced diet for adult man and woman who have the habit of moderate work are given below:

Items	Man		Women	
	Vegetarian gm	Non Vegetarian gm (KCal)	Vegetarian gm	Non Vegetarian gm
Cereals	475	475 (1860)	350	350
Pulses	80	65 —	70	55
Green leafy vegetables	125	125 —	125	125
Other vegetables	75	75 —	75	75
Roots & Tubers	100	100 —	75	75
Fruits	30	30 —	30	30
Milk	200	100 (67)	200	100
Fats & oils	40	40 (370)	35	40
Meat & Fish	—	30 (31)	—	30
Eggs	—	30 (52)	—	30
Sugar & Jaggery	40	40 (160)	30	30

(Total KCal=2540 roughly)

In case of sedentary habit the amount of diet should be less than the above tables and in case of heavy worker the diet should be increased is sufficient amount. Parentheses contain approximate KCal.*

TABLE : 3.

Minerals and vitamins need for a balanced diet.

Nutrient	Amount
Calcium	0.8 gm
Phosphorus	1.4 gm
Iron	40 mg
Vitamin A	750 mg
Vitamin B	1.8 mg
Vitamin C	50 mg

(It should be remembered that adequate amount of water is one of the most essential constituent of diet.)

THE PRINCIPLES OF PREPARATION OF A BALANCED DIET

The principles of preparation of a balanced diet are based on the following various factors:

1. The need of total calories in diet with the knowledge of actual energy expenditure for 24 hours.
2. The 'proximate principles' in the diet.
3. Quantity and quality of various foodstuffs.
4. Supply of adequate vitamins and minerals.
5. Selection of foods with the local availability.

* Kilo calories.

6. Care for a vegetarian diet.
7. Consideration of age and sex.
8. Physical status etc.

1. **The need of total calories**—The need of the total calories of adult is based on the measurement of total energy expenditure during 24 hours. It is usually measured by determination of oxygen consumption in various state of activities and then it is expressed as kilocalories (Kcal). However, energy expenditure for an adult people who performs moderate physical work has been found to be approximately 73 Kcal/hour or 1752 Kcal/day.

As 30% of the dietary calories are wasted in excretion through faeces and urine, the dietary calories may therefore be such that a deduction of 30% of total calories should equal to the daily energy expenditure. It is explained in the following way:

If X=Total dietary calories.

Wastage calories=30% of X=0.30 X.

Daily energy expenditure=1750 Kcal (say).

Thus, Total Dietary calories—Wastage calories=Daily energy expenditure.

Or, $(X-0.30\ X) = 1750$ Kcal.

Or, $X\ (1-0.30) = 1750$ Kcal.

Or, $X = \dfrac{1750}{0.70} = 2500$ Kcal.

Or Total dietary calories = 2500 Kcal.

Thus the total dietary calories of adult may be approximately 2500 Kcal/day (see table 1).

The balanced diets for adult man who has the habit of moderate work would be approximately 2500 Kcal/day. The industrial workers who perform manual labour may need more than this figure. Body weight would be decreased if the calories input become less than the calories output. Thus the *frequent checking of body weight may reveal whether the input calories are adequate or balanced.*

2. **Proximate principles**—Protein, fat and carbohydrate are the chief source of energy and these are called proximate principles.

3. **Quantity and quality of food**—The qualities of protein and fat are of primary importance in addition to their quantities in the diet. All the essential amino acids and the essential fatty

acids must be supplied daily in the diet. The selection of proteins in diet must be of *high biological value* and high *protein efficiency ratio* (see page 314). The food containing unsaturated fatty acids should be given preferentiably. Ground nut oil is unique in this sense and this may be given at least 15 to 20 gms. daily in the diet. Saturated fatty acids must be avoided in large doses as it causes a rise of blood cholesterol level. Vegetable oils contain essential fatty acids.

4. **Vitamins and minerals**—These are essential for many vital processes of life. These must be supplied daily in the diet. Fresh vegetables and fruits may be given in addition to chief diet. Most of the common foods are rich in vitamins and minerals. Some uncooked foods should be selected as cooking causes loss of some vitamins.

5. **Local availability of foods**—Diet is usually based to the local availability of foods. Thus dietary habits vary from one place to other place. Choice of diet also varies due to varieties of food in different seasons.

6. **Vegetarian diet**—Some people are strictly vegetarian and they do not take fish, meat and egg in their diet. Thus vegetarian diet must contain more milk and pulses than those of non-vegetarian.

7. **Age and sex**—The growing children need extra calories than their calories output. At least 30% more calories should be given over their calories output.

Calories need of males are usully higher than the females of same age groups.

The dietary intake of calories in pregnant and lactating mother would be obviously much greater than their actual energy expenditure daily.

8. **Physical status**—Greater is the physical status greater would be the input of the dietary calories. Athlets need more calories in their diets as they perform more physical exercise.

Thus the above factors are to be considered to prepare a balanced diet for different people. Whatever may be the diet, it should be palatable.

Preparation of diet chart needs the special knowledge in biochemical compositions of various common foodstuffs. These are summarised in table 4. (page 321-323).

DIGESTION OF FOOD IN THE ALIMENTARY CANAL

The digestive canal is a long muscular tube. It consists of the following parts from above downwards: the mouth, tongue, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anal canal. These are shown in fig. 1.

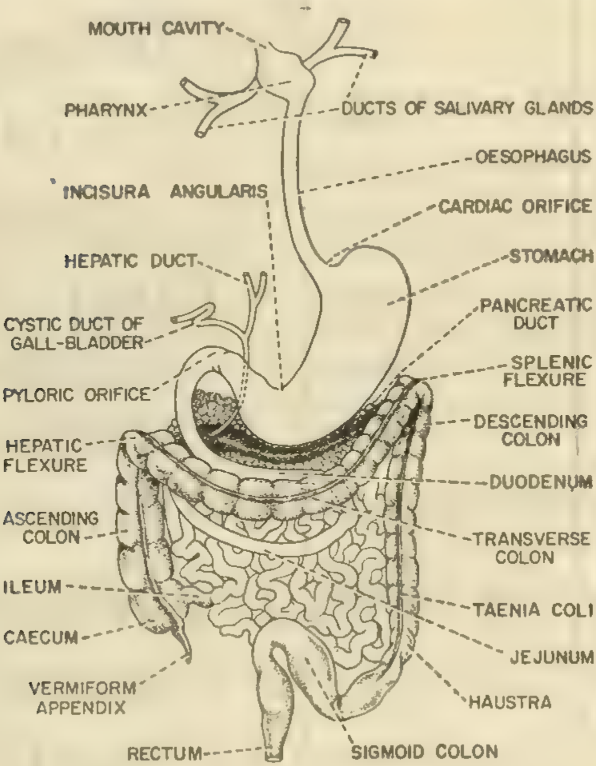


Fig. 1. Various parts of the alimentary canal.

There are five digestive juices: (1) saliva, (2) gastric, (3) pancreatic, (4) intestinal and (5) bile.

One juice does not contain all the enzymes necessary to digest all the different types of foodstuffs. One particular juice cannot digest a particular type of food upto completion. It usually digests only upto a certain stage and then hand over it to the next digestive juice for further digestion.

It is noted that saliva is slightly acid, gastric juice is strongly acid, but pancreatic juice is strongly alkaline. *These alternate*

TABLE : 4.

BIOCHEMICAL COMPOSITIONS OF VARIOUS FOODSTUFFS

Proximate principles, minerals and vitamins.
(All the values given are per 100 gm of edible portion)

Name of foodstuff	Moisture, gm	Protein, gm	Fat, gm	Carbohydrate, gm	Energy, Kcal	Minerals, gm	Calcium, mg	Phosphorus, mg	Iron, mg	* Carotene μg.	Thiamine, mg	Riboflavin, mg	Niacin, mg	Vitamin C, mg
Rice, perboiled, handpounded	12.6	8.6	0.6	77.4	349	0.9	10	280	2.8	9	0.27	0.12	4.0	0
Rice, perboiled, milled	13.3	6.4	0.4	79.0	346	0.7	9	143	4.0	—	0.21	0.05	3.8	0
Rice, raw, handpounded	13.3	7.5	1.0	76.7	346	0.9	10	190	3.2	2	0.21	0.16	3.9	0
Rice, raw, milled	13.7	6.8	0.5	78.2	345	0.6	10	160	3.1	0	0.06	0.06	1.9	0
Wheat (whole)	12.2	12.1	1.7	69.4	341	2.7	48	206	11.5	29	0.49	0.29	4.3	0
Wheat flour (whole)	13.3	11.0	0.9	73.9	348	0.6	23	355	2.5	25	0.12	0.07	2.4	0
Maize, dry	14.9	11.1	3.6	66.2	342	1.5	10	348	2.0	90	0.42	0.10	1.8	0
Lentil	12.4	25.1	0.7	59.0	343	2.1	69	293	4.8	270	0.45	0.20	2.6	0
Bengal gram dhal	9.9	20.8	5.6	59.8	372	2.7	56	331	9.1	129	0.48	0.18	2.4	1
Green gram dhal	10.1	24.5	1.2	59.9	348	3.5	75	405	8.5	49	0.72	0.15	2.4	0
Peas, dry	16.0	19.7	1.1	56.5	315	2.2	75	298	5.1	39.0	0.47	0.19	3.4	0
Potato	74.7	1.6	0.1	22.6	97	0.6	10	40	0.7	24.0	0.10	0.01	1.2	17
Apple	84.6	0.2	0.5	13.4	59	0.3	10	14	1.0	0	—	—	0	1
Grape	82.2	0.6	0.4	13.1	58	0.9	20	23	0.5	3	0.04	0.03	0.2	1

* Carotene is the precursor of vitamin A.

TABLE : 4. (Contd.)

Name of foodstuff	Moisture, gm	Protein, gm	Fat, gm	Carbohydrate, gm	Energy, Kcal	Minerals, gm	Calcium, mg	Phosphorus, mg	Iron, mg	* Carotene μg.	Thiamine, mg	Riboflavin, mg	Niacin, mg	Vitamin C, mg
Banana	70.1	1.2	0.3	27.2	116	0.8	17	36	0.9	78	0.05	0.08	0.5	7
Mango	81.0	0.6	0.4	16.9	74	0.4	14	16	1.3	27.4	0.03	0.09	0.9	16
Guava	81.7	0.9	0.3	11.2	51	0.7	10	28	1.4	0	0.02	0.03	0.4	212
Orange	87.6	0.7	0.2	10.9	48	0.3	26	20	0.3	1104	—	—	—	30
Milk, Cow's	87.5	3.2	4.1	4.4	67	0.8	120	90	0.2	174	0.05	0.19	0.1	2
Milk, Buffalo's	81.0	4.3	8.8	5.0	117	0.8	210	130	0.2	160	0.04	0.10	0.1	1
Egg, hen	73.7	13.3	13.3	—	173	1.0	60	220	2.1	600	0.10	0.4	0.1	0
Egg, duck	71.0	13.5	13.7	0.8	181	1.0	70	260	3.0	540	0.12	0.26	0.2	—
Fowl's Meat	72.2	25.9	0.6	—	109	1.3	25	245	—	—	—	0.14	—	—
Goat's meat	74.2	21.4	3.6	—	118	1.1	12	193	—	—	—	—	—	—
Rohu, Fish	76.7	16.6	1.4	4.4	97	0.9	650	175	1.0	—	0.05	0.07	0.7	22
Prawn	77.4	19.1	1.0	0.8	89	1.7	323	278	5.3	0	0.01	0.1	4.8	—
Magur fish	78.5	15.0	1.0	4.2	86	1.3	210	290	0.7	—	—	—	0.5	11
Jack fruit	76.2	1.9	0.1	19.8	88	0.9	20	41	0.5	175	0.03	0.13	0.4	7
Pineapple	87.8	0.4	0.1	10.8	46	0.4	20	9	1.2	18	0.20	0.12	0.1	39

* Carotene is the precursor of vitamin A.

acid and alkaline reactions help to maintain blood reaction constant.

The mechanisms of secretion of various digestive juices are usually governed by the following stimuli : (a) Nervous, (b) Chemical (hormone and diet) and (c) Mechanical.

Nervous stimuli are reflex in nature. Contact of food on the tongue or other parts of gastrointestinal tract, sight of food, smell of food, etc. act on the sensory nerve endings and the generated nerve impulses via the central nervous system, trigger the corresponding motor nerve of the gland into action, as a result secretion occurs.

Chemical stimuli are governed by the chemical substances i.e., hormones and dietary food particles.

Mechanical stimuli usually stretch or distretch of the organs by solid or liquid foods which stimulate the local sensory nerve endings and thus local reflexes occur.

Mechanism of gastric secretion involves all these stimuli except mechanical. *Salivary secretion is purely a nervous mechanism. Pancreatic secretion involves both nervous and chemical processes. Bile secretion is mainly governed by the chemical phenomenon. The secretions of intestinal juices involve all the three processes.*

Salivation is operated by two types of reflexes :

(1) *Conditioned or acquired.*
(2) *Unconditioned or inherent or inborn reflex.*

The existence of conditioned reflex is proved by the fact that even the sight or smell of food can stimulate salivation, although food is not actually given to the mouth. While in the unconditioned reflex the food is actually given i.e., chewing and it reflexly stimulates secretion.

The secretion of *gastric juice* is also governed by these two types of reflexes. It has been proved by the two very important experiments : (1) *Sham feeding*, (2) *Pavlov's pouch.* (Fig. 2 & 3).

Sham feeding shows that food is not entering into the stomach during swallowing of the foods but gastric secretion occurs.

Preparation of Pavlov's pouch is usually done in the experiment of sham feeding. Gastric secretion could be demonstrated as both conditioned and unconditioned reflexes.

Pancreatic secretion is governed both by nervous and chemical phase. While *bile secretion* is entirely dependent on the chemical stimuli.

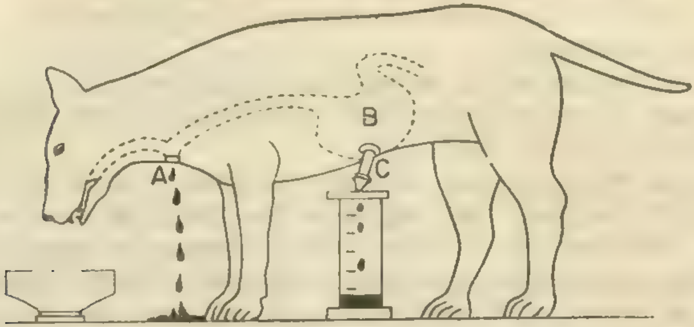


Fig. 2. Sham feeding. A—Cut oesophagus shows exit of food after swallowing, B—Stomach, C—Canula in the fistula.

Under normal conditions, presence of food in the intestine sets up the *mechanical irritation* which reflexly stimulates the *secretion of intestinal juices* through local nerves.

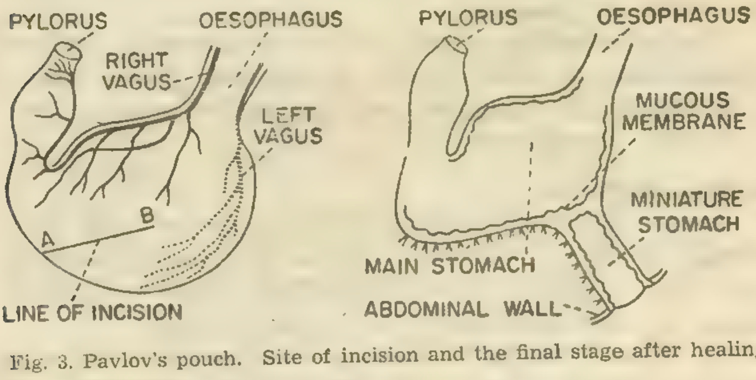


Fig. 3. Pavlov's pouch. Site of incision and the final stage after healing.

DIGESTION OF FOODSTUFFS

Digestion is a process of biochemical transformation of larger food particles in the gut enzymatically into a simple and smaller form suitable for absorption and assimilation. Digestion is carried out in 'relays' as one digestive juice does not possess all the enzymes necessary for the digestion of all the varieties of foodstuffs completely.

The digestion of foodstuffs are given in the following ways :—

Digestion of carbohydrate

The carbohydrate food is usually given as polysaccharides (starch, glycogen, dextrin), disaccharides (lactose, maltose, sucrose) and monosaccharides (glucose and fructose).

Saliva contains chiefly salivary amylase or ptyalin enzymes and traces of maltase.

Ptyalin acts on the boiled starch and converts it into maltose. Ptyalin action chiefly takes place in the stomach before HCL concentration becomes high.

In the gastric juice, there is no carbohydrate splitting enzyme, but HCL of gastric juice may cause some hydrolysis of sucrose.

Pancreatic juice contains pancreatic amylase and most of the starch is converted into maltose within a few minutes. *Amylase is not present in the pancreatic juice of infant upto 6 months of age.*

The succus entericus (intestine) secretes juice which converts maltose to glucose by maltase. Thus starch is completely hydrolysed to glucose. The other disaccharides taken in the food are hydrolysed by lactase and sucrase present in this juice. Sucrose is converted into glucose and fructose; and lactose is converted into glucose and galactose.

Thus the digestible carbohydrates are all converted into many monosaccharides in which form they are absorbed. *The process of starch digestion is slow and prolonged so that sudden rise of blood sugar is prevented.*

Digestion of Protein

Protein digestion starts in gastric juice and ends in the succus entericus. Pepsin is a proteolytic enzyme and it is present in the gastric juice. It acts with the help of HCL in the stomach and converts all digestible proteins upto the peptone stage.

Pepsinogen in the peptic cells of the stomach is converted into active form as pepsin with the help of gastric HCL. It attacks the peptide linkages of the protein molecules. The action of pepsin on the living gastric mucous membrane is prevented by the antipepsin present in the gastric mucosa.

Trypsin is a proteolytic enzyme present in the pancreatic juice. Trypsinogen remains as inactive forms and is converted to trypsin by the action of enteropeptidase in the succus entericus. This causes convertion of proteose, peptones, polypeptide into lower peptides. Some peptides may be convertod into amino acid e.g., leucine and tyrosine.

In the succus entericus aminopeptidase and dipeptidase act in alkali medium and convert peptides into amino acids completely in which form these are absorbed.

Digestion of lipid or fat

In the gastric juice, lipase is a lypolytic enzyme which breaks neutral fat into glycerol and fatty acids.

Fat digestion is mainly carried out in the duodenum by pancreatic lipase (Steapsin). Fat digestion is nearly completed by the pancreatic juice. Bile salts help fat digestion in a number of ways.

Succus entericus also contains another lipase enzymes. It deals with that little quantity of fat which might have accidentally escaped pancreatic digestion.

Pancreatic lipase hydrolyses triglycerides to fatty acids and two monoglycerides. Two menoglycerides converted to 1-monoglyceride and hydrolysed by pancreatic lipase to fatty acids.

COMPOSITION OF SALIVA, GASTRIC, PANCREATIC AND INTESTINAL SECRETION AND BILE

1. Composition of Saliva

Human saliva has the following composition :—

(A) Water—99.5%

(B) Solid—0.5%

1) Inorganic :—

About 0.2% is inorganic salts. These are NaCl, KCL, acid and alkaline sodium phosphate, $CaCO_3$, Calcium phosphate.

2) Organic :—

0.3% is the organic constituents. Ptyalin (salivary amylase), lipase, carbonic anhydrase and lysozyme. Urea, amino acids, cholesterol and vitamins are found in small quantity.

Main function of saliva is to help in digestion.

Reaction is usually slightly acidic (PH = 6.02—7.05)

2. Composition of Gastric juice

The composition of gastric juice of hauman is described below :—

(A) Water—99.45%

(B) Solid—0.55%

Inorganic :—NaCl, KCl, $CaCl_2$ and HCl.

Organic :—Pepsin, Gastric renin, Gastric lipase are the main enzymes of gastric juice. Main function is digestion of food-stuffs with the process of hydrolysis mainly.

Reaction is strongly acid due to presence of HCl ($pH = 0.9 - 1.5$).

Composition of pancreatic juice

Inorganic :—The distinguishing characters of pancreatic juice is the presence of high bicarbonate and thus the reaction is alkaline ($pH = 8.0$—8.3 in dog).

Organic :—Pancreatic juice contains maximum number of enzymes. These are trypsinogen, chymotripsinogen nucleotidase, pancreatic lypase, cholesterol estarase and amylase.

Main function is to help in digestion.

Composition of intestinal juice

(A) Water—98.5%

(B) Solid—1.5%

Inorganic :—The bicarbonate concentration is very high and pH varies from 6.3—9.0 (average = 8.3).

Organic :—The most of the important enzymes are :—

1) Proteolytic :—Erepsin, amino peptidase are the main enzymes.

2) Carbohydrate-splitting enzyme :—

Amylase, sucrase, maltase, lactase are the main enzymes.

3) Fat-splitting—Lipase is the main enzyme.

Main funtcion is to help in proper digestion.

Composition of Bile

Bile is a product of secretion and it is also an excretion of the liver. In the gall-bladder bile remained as a high concentration and its alkalinity is reduced.

Liver bile is definitely alkaline. PH = 7.7.

1) **Inorganic** :—Chlorides, carbonates, and phosphates of Na, K, Ca, and $NaHCo_3$.

2) **Organic** :—Cholesterol, lecithin, bile pigments etc.

Bile pigments are 1) Bilirubin is a golden colour pigment while biliverdin is green in colour. These are two pigments.

Bile salts are sodium taurocholate and sodium glycolate. These are the sodium salts of taurocholic and glycolic acids respectively.

Main function of the bile is to help in digestion of the food stuffs.

ABSORPTION OF FOOD

Absorption is a process by which the end products of digestion pass through the intestinal epithelium to the blood stream.

Absorption of carbohydrate

End products of carbohydrate digestion are the monosaccharides. These are highly soluble in water. The physical forces like diffusion, osmosis, filtration etc. play a considerable part in their absorption. Glucose is maximally absorbed in jejunum. Carbohydrates are completely absorbed through the portal system which shows a higher concentration of sugars during absorption. Verzer has suggested that during absorption, phosphorylation of sugar takes place and hexose phosphate is formed and this helps to lower down the concentration of free glucose. Adrenal cortex and insulin control the process of phosphorylation. Thiamine, pantothenic acid and pyridoxine may help in the process of absorption.

Absorption of protein

End products of protein digestion are the amino acids. Small amounts of peptides may be absorbed from the alimentary canal. Absorption of amino acids might be either an active or a passive process. The amino acids chiefly pass through the portal system. Negligible amount may enter the lymphatics. Vitamin B_6 and M_n^{++} have some roles in the process of absorption of amino acids.

Absorption of fat

There are two theories regarding fat absorption. One is lipolytic hypothesis another is partition hypothesis.

Lipolytic hypothesis have been given by Pfluger, Verzer and McDougall. The partition hypothesis is given by Frazer.

Lipolytic hypothesis—Triglycerides (fats) are absorbed mainly in the lymphatics after their resynthesis from fatty acid and glycerol in the mucosal epithelial cells.

Partition hypothesis—Lipids are absorbed partly in emulsified form without hydrolysis into the lymphatic channel and pass into the blood through the thoracic duct. Fat is also absorbed in the form of fatty acid bile salt complex into the portal vein.

Recent studies reveal a considerable light in the mechanism of fat absorption. Triglycerides hydrolyse to 2—monoglycerides and free fatty acid. The salts spontaneously aggregate with monoglycerides and form micells when bile salt attains a certain value known as critical micellar concentration. Micell dissolves free fatty acids, cholesterol and fat soluble vitamins. The monoglycerides and fatty acids are separated from micells to be absorbed in the duodenum and jejunum by resynthesis of triglyceride. Resynthesised fat is absorbed into the lymph. Chylomicron is the droplets of fat

and is formed by aggregation of fat molecules before the delivery of resynthesized fat into lymph.

METABOLISM

Carbohydrate Metabolism

Carbohydrate absorbed into the blood are mainly hexose monosaccharides, (glucose, fructose and galactose). All the hexose monosaccharides are converted into glucose in the cells for oxidation and partly for their storage as glycogen through UDPG cycle (uridine diphospho-glucose). Normally glucose is burnt by the tissue to supply major portion of the energy.

The metabolism of carbohydrate is mainly governed by the following processes: (1) *Glycolysis*, (2) *Glycogenesis*, (3) *Glycogenolysis*, (4) *The citric acid cycle*, (5) *Hexose monophosphate shunt and* (6) *Gluconeogenesis*.

Glycolysis—The oxidation of glucose or glycogen to pyruvate and lactate is one by the Embden-Meyerhof pathway. This process is called glycolysis.

Glucose enters into the glycolytic pathway by phosphorylation to glucose-6-phosphate by hexokinase enzyme. ATP (adenosine triphosphate) is required as phosphate doner for phosphorylation. One high energy phosphate bond of ATP is utilized and ADP (adenosine diphosphate) is produced. The pathway of glucose-6-phosphate to pyruvate is known as glycolytic pathway: These are shown briefly in the following way:—

Glycogen ⇆
Glucose ⇌ Glucose-6-phosphate
⇅
Fructose-1, 6-Diphosphate
⇅
Triose Phosphate
⇅
Phosphoenol pyruvate
↓
Pyruvate⇌Lactate (Cori cycle)
↓
Citric acid cycle pathway
(in presence of oxygen)

8 mols of ATP are generated per mol of glucose during break down to pyruvate as net gain.

Most of the glycolytic pathways are reversible. The reactions are performed by various enzyme systems. It produces net 8 mols of ATP.

Citric acid cycle—The citric acid cycle (Krebs' cycle or tricarboxylic acid cycle) is a sequence of reactions in which acetyl Co A is metabolized to CO_2 and H atoms. Acetyl Co A is first condensed with a 4-Carbon acid, oxaloacetic acid to form citric acid and HS—Co A. In a series of 7 subsequent reactions, 2 CO_2 molecules are

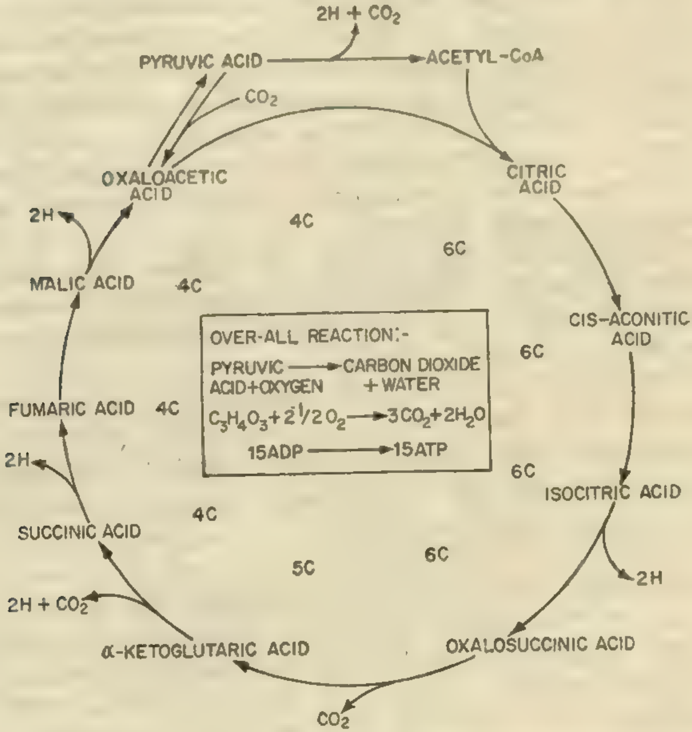


Fig. 4. Citric acid cycle.

split off, regenerating the oyaloacetic acid. 4 pairs of H atoms are transferred to produce 12 ATP and 4 H_2O, of which 2 H_2O are used in the cycle. The citric acid cycle is the common pathway for oxidation of carbohydrate to CO_2 and H_2O. *The citric acid cycle requires O_2, and does not function under anaerobic conditions.* The pathway of citric acid cycle is shown in the fig. 4. The citric acid cycle generates 12 mols of ATP. ATP is the stored energy and is also an immediate source of energy. Total 15 ATP is the net gain when pyruvic acid is oxidized through citric acid cycle i.e., 3-C of pyruvic acid produces 15 mols of ATP. The 6-C of glucose will produce 30 mols of ATP through citric acid cycle

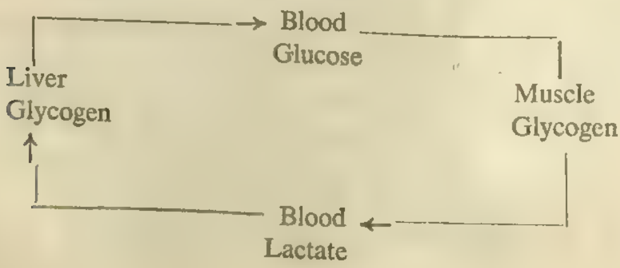
and 8 mols of ATP are gained through glycolysis. *Thus break down of glucose to CO_2 and H_2O produces net* 38 *mols of* ATP.

Hexose monophosphate (HMP) shunt or pentose phosphate pathway—The sequence of reactions of the shunt pathway may be divided into two phases. In the first, glucose 6-phosphate undergoes dehydrogenation and decarboxylation to give the pentose ribulose-5-phosphate. In the second phase, ribulose-5-phosphate is converted back to glucose-6-phosphate by a series of reactions. Pentose is synthesized for the synthesis of nucleotides. Energy formed in this path is 36 ATP per molecule of glucose if all the $NADPH_2$ (reduced Nicotinamide Adenine Dinucleotide Phosphate) are oxidised in the mitochondria to NADP. Vitamin C may be synthesized through this pathway.

Glycogenesis—The synthesis of glycogen from glucose is called glycogenesis. Glycogen is the storage form of glucose ; it is present in most of the body tissues, *but the major supplies are in the liver and in skeletal muscles.*

Glycogenolysis—The break down of glycogen is known as glycogenolysis. Glucose is the main end product in the liver ; and pyruvate and lactate are the main end products in the muscles.

The lactic acid that emerges from the muscles, is carried to the liver through blood stream where it is reconverted into glycogen. This glycogen is again mobilized in the form of glucose to the blood stream. Muscles take up this glucose and recover its lost glycogen. This cycle is known as Cori cycle. Cori cycle is mostly operative at the end of exhaust muscular exercise to recover its muscle glycogen. About 4/5th of lactic acid is resynthesized to glycogen and 1/5th of it undergoes oxidation reaction to meet up the deficit energy for a given muscular work. The magnitude of this work may be identified as an anaerobic work where deficit of adequate O_2 is the main cause.



Cori Cycle

Gluconeogenesis—The formation of glucose or glycogen from noncarbohydrate sources is known as gluconeogenesis. *The pathways are mainly the citric acid cycle and glycolysis.* The principle substrates for gluconeogenesis are glucogenic amino acids, lactate and glycerol.

In the post absorptive state the blood glucose concentration of man varies between 80 to 100 mg/100 ml blood. In diabetes blood glucose exceeds this normal value to a high level. Insulin hormone regulates blood glucose level. Deficiency of insulin causes diabetes and thus raises blood glucose level. Details would be discussed later.

Lipid Metabolism

The biologically important lipids are the neutral fats (triglycerides), the phospholipids, the sterols and their products are glycerol and ketone bodies. The phospholipids are constitients of cells, especially in the nervous system. The sterols include the various steriod hormones and cholesterol. The calorific value of fat is 9.3 Kcal/gm and it is the most concentrated form in which potential energy can be stored.

Fat oxidation—The glycerol liberated when triglycerides are hydrolysed and can be converted to phosphoglyceraldehyde and then to glucose or to CO_2 and H_2O. *The fatty acids are broken down to acetyl Co A which enters the citric acid cycle.* Fatty acid oxidation apparently occurs in the mitochondria. The energy yield of this process is highly large. Catabolism of 1 *mol of six carbon fatty acid through the citric acid cycle to CO_2 and H_2O generates* 44 *mols of* ATP, *compared to the* 38 *mols generated by catabolism of* 1 *mol of the six carbon carbohydrate, glucose.*

Phospholipids and sterols are bound to the albumin, α—globulin, and β—globulin fractions of the plasma proteins. These are *lipid protein complex.*

Fatty acids are oxidized physiologically by β—oxidation. Several enzymes collectively called fatty acid oxidase which catalyzes the oxidation of fatty acids to accetyl Co A, the system being coupled with the phosphorylation of ADP to ATP. In many tissues, accetyl Co A units condense to form aceto accetyl Co A which produces acetoacetic acid.

β—Hydroxybuteric acid and acetone are formed from acetoacetic acid and these are known as ketone bodies. The

increase of ketone bodies in the blood is known as ketonemia. Ketonuria is called when ketone bodies are found more in the urine.

Fat synthesis—Many tissues can synthesize fatty acids from acetyl Co A. In fat depots, the fatty acids are combined with glycerol to form neutral fats in mitochondria. *Glucose may be converted into fat through acetyl-Co A.*

Protein Metabolism

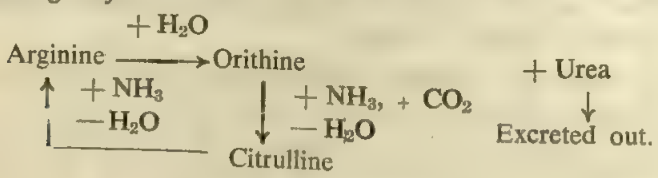
Metabolism of amino acid is usually leading to a formation of urea which is excreted in the urine. 1 gm of protein yields 4.1 calories when it breaks down. While breaking down, amino acids exert a specific dynamic action (SDA) on tissue metabolism. SDA of protein is about 30%.

Deamination and transamination are the major processes of break down of amino acids.

Deamination is the process by which the—NH_2—radicle of amino acid is taken up. It is carried out chiefly in the liver with help of an enzyme known as deaminase. Deamination may also take place by the transaminase enzyme which transfers the amino group (—NH_2) of the amino acid to a keto acid. With this process the amino acid molecule is broken down into two parts: (1) the nitrogenous part (ammonia) and (2) The non nitrogenous part (ketonic acid or aldehyde or a hydroxy acid).

Fate and function in the Nitrogenous part

Most of the ammonia is usually converted into urea. Although ammonia may be excreted as ammonium salts, but the vast majority is excreted as urea. Urea is formed by a cyclical process which is known as *ornithine cycle*. *Arginine*, an amino acid is broken down by arginase into urea and ornithine. Ornithine unites with one molecule of ammonia and CO_2 to produce citrulline in the following way:



Krebs—Henseleit cycle

Citrulline combines with another molecule of NH_3 to form arginine. Thus the cycle repeats and at each cycle one molecule of urea is formed and excreted.

Ammonia may be utilized for the synthesis of simple amino acids, such as glycine, alanine etc. Creatine, purine and uric acid may also be synthesized from ammonia.

Fate and function of Non-nitrogenous part

The non-nitrogenous residues of some amino acids are utilised in the body as carbohydrates. Glycine, alanine, lysine, valine and tyrosine etc. are called *antiketogenic amino acids or glucogenic amino acids* i.e., these amino acids break down to form glucose.

Some parts of the amino acids undergo the fate of fats which yield no glucose but give rise to ketone bodies. Phenylalanine and tyrosine are known as *ketogenic amino acids* as these are converted to ketone bodies.

The sulphur and phosphorus, derived from the non-nitrogenous part of the amino acids are converted into various sulphur and phosphorus compounds and are excreted as such in the urine.

Transamination, Amination and Deamination

Transamination is a reversible process as well as combined process of deamination and amination. Transaminase is the enzyme for the reaction. In most cases there occurs a transference of aminogroup from amino acid to keto acid. Pyridoxal phosphate (a vitamin B_6 derivative) acts as the coenzyme in break down of amino acid to keto acid. Keto acid may form carbohydrate. Alanine, leucine, tyrosine etc. take part in the transamination reaction. *Lysine and theonine show no transamination reaction.*

Oxidative deamination of amino acids occurs in the liver. An amino acid is formed by dehydrogenation, and this compound is hydrolysed to the corresponding keto acid with the liberation of ammonia. Glutamic acids can take up NH_3 to form corresponding amine and is known as amination e.g., *Glutamine is formed by union of ammonia and glutamic acid.*

Transmethylation

The amino acid readily donates its terminal methyl group ($-CH_3$) for methylation of various compounds. This is known as transmethylation. The $-CH_3$ group may be transferred to other compounds for the synthesis of choline or creatine.

Amino acid pool

The amino acids formed by endogenous protein break down are in no way different from those derived from ingested protein. With the latter they form a common amino acid pool that supplies the need of the body. These are shown in the figure 5.

Nucleoprotein metabolism

Nucleoproteins contain phosphoric acid and also other prosthetic group. The nucleic acids combine with basic protein to form nucleoprotein. The nucleic acids viz., DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are very important. *DNA is the chief nucleic acid and is found in chromosome whereas RNA is found in the nucleus and the cytoplasm and help in the syn-*

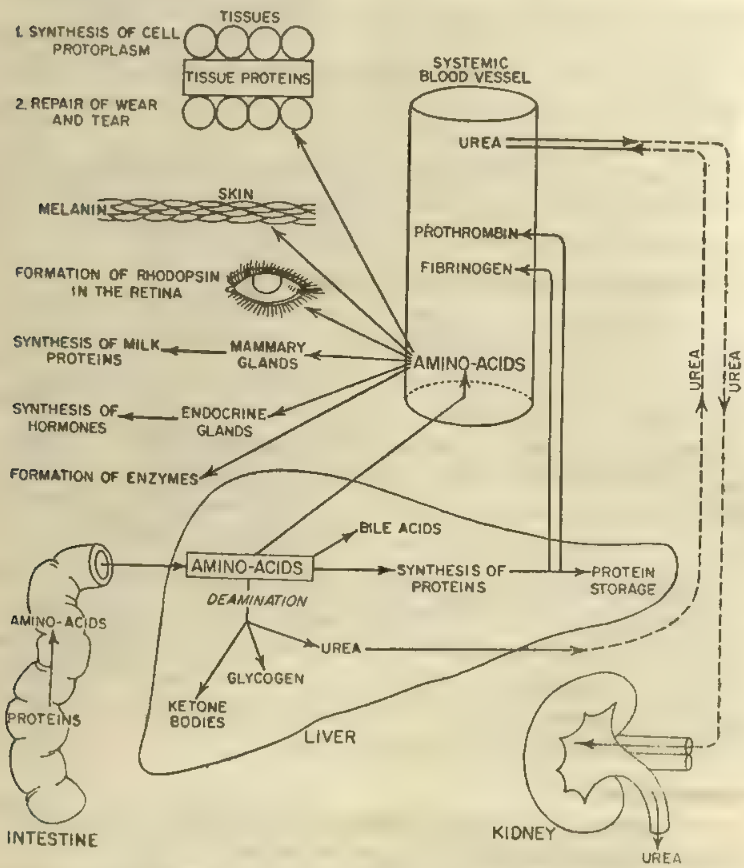


Fig. 5. Amino acid pool showing fate and function of amino acid.

thesis of protein. The break down and synthesis of RNA are continuously going on within the cell with the help of intracellular enzymes. *DNA is a stable compound and controls the heriditary characteristic of the cells.* There are two kinds of tissue nucleotidases which help in endogenous metabolism of the uncleotides.

The phosphonucleotidase splits off phosphoric acid and forms nucleosides. Purine nucleotidase takes away the purine bases, leaving phosphoric acid molecule to combine with carbohydrate. The end product of purine metabolism is chiefly uric acid and is excreted in the urine.

AEROBIC AND ANAEROBIC METABOLISM AND BASAL METABOLISM

Glycolysis is the process of carbohydrate metabolism. It is already discussed earlier. The end products are pyruvic or lactic acid. It does not require oxygen. Thus in absence of oxygen (anaerobic condition) pyruvic acid is reduced to lactic acid by reduced nicotinamide adenine dinucleotide (NAD 2H i.e. DPN H_2).

Thus lactic acid is formed under anaerobic metabolism. It is noted that 1/5th of it is oxidised to CO_2 and H_2O. While 4/5th are resynthesized into glycogen in the liver through Cori cycle.

Aerobic metabolism means oxidation of pyruvic acid through TCA cycle which has been described earlier.

It is noted that per oxidation of one molecule of glucose to CO_2 causes net gain of 38 ATP (aerobic metabolism). While in anaerobic condition only 5 ATP are produced per hexose unit of glycogen. Thus under anaerobic metabolism 13 ATP are produced while in aerobic condition 38 ATP are produced.

BASAL METABOLISM

Basal Metabolism Rate (B.M.R.) defines the amount of heat energy when the subject is considered to lye down with a maximal physical and mental rest under comfortable conditions of temperature, pressure and humidity following 12-18 hours of last meal. Usually subject takes his last meal at 8 O' clock in the previous night and measurement is taken usually between 8 to 10 A.M. in the next day.

In adult male, B.M.R. is about 40 kilocalories per square metre of body surface per hour. In female it is slightly lower i.e., 37 kilocalories.

Surface area $= 0.0071 \times \text{Weight}^{0.425} \times \text{Height}^{0.725}$ (Square metre)

Factors affecting basal metabolic rate

1. Age :—As children possess greater surface area in proportion to their body weight, their B.M.R. is higher. B.M.R. decreases gradually with advance of age.

2. Sex :—In female B.M.R. is lower in comparison to male.
3. Habit :—Athletes have a slightly higher B.M.R.
4. Climate :—In cold climate, B.M.R. is slightly higher.
5. Diet :—Prolonged under nutrition lowers the B.M.R.
6. Hormone :—Growth hormone increases the B.M.R. about 20%.
7. Pregnancy :—B.M.R. increases in pregnancy due to combined effect of mother and baby.
8. Body temperature :—In fever, a rise of 1°C causes an increase of 12% in B.M.R.
9. Drugs :—Caffeine increases the basal metabolic rate. Thus caffeine helps in maintenance of body temperature during winter and an immediate drinking of coffee causes removal of cold sensation due to its presence of caffeine.

Measurements of B.M.R.

The B.M.R. is measured with spirometer where the subjects breath in and out pure O_2 with the help of CO_2 absorber mechanism. The oxygen uptake is considered for a certain period of 5 to 6 min and then its calorific value is indirectly calculated out. 1 litre O_2 consumption = 5 kilocalories roughly. Once O_2 consumption is known it is calculated out for a period of one hour and it is then divided by surface area (square metre) to get the normal B.M.R. $\pm$10% above or low is to be considered abnormal. B.M.R. is low in Indian in comparison to Western.

INCREASED METABOLISM OF WORK AND PHYSICAL EXERCISE

Physical exercise causes an increase in metabolic work by the break down of glycogen at a higher rate. In normal state metabolic work is performed with 250 ml of O_2 extraction per min. by the tissues. In Indian this value is 210 ml/min.

O_2 extraction is an index or measurement of metabolic work of the body. It is found that metabolic work increases during heavy exercise where O_2 extraction by the tissue may reach 2-4 litre per min. It is achieved by the cooperation of increased ventilation and cardiac output. Exercise needs energy, energy is supplied by the tissue metabolism which is assisted by increased work of heart and lungs, so that more blood and O_2 could be circulated to the tissue per unit time.

Under nomal resting condition both aerobic and anaerobic work proceed side by side. In normal resting blood lactic acid is found

to be 10 mg per 100 ml blood, whereas during exercise it rises more than 100 mg/100 ml blood and exhaust work is terminated due to accumulation of large quantity of lactic acid in the muscles which produces fatigue. It is already discussed that 4/5th of lactate goes back to resynthesize muscle glycogen through Cori cycle. Remaining 1/5th of lactate undergoes oxidation reaction and thus pays the O_2 debt of heavy work during recovery period of exercise. It seems worthwhile to mention that maximum O_2 uptake capacity of man is limited and it is found that V O_2 max (volume of maximum O_2 uptake capacity during exercise) is 40 ml/min/kg body weight. This is applicable for standard Indian man whose body weight was 50 kg and Height = 163 cm.

2

TRANSPORT OF NUTRIENTS AND GASES IN THE BODY

(Composition and function of Blood and Lymph. Course of circulation of blood through the human heart. Cardiac output. Internal and External Respiration. Mechanism of Inspiratory and Expiratory movements. Compartments of Lung air. Composition of Inspired, Expired and Alveolar air.)

The Nutrients and Oxygen are vital important for living organism. Blood, plasma and lymph are the main vehicles for the transport of various nutrients and gases in different tissues of the body.

COMPOSITION OF BLOOD

Blood is a complex fluid which is composed of two parts: (1) Plasma and (2) Cells. The plasma constitutes about 55 per cent and the cells about 45 per cent.

Cells—There are three types of cells. These are (1) Red blood corpuscles or erythrocytes (RBC), (2) White blood corpuscles or leucocytes (WBC), (3) Platelets or thrombocytes.

Plasma—These are the liquid part of the blood. The composition of plasma is as follows :—

(1) Water—91 to 92%.

(2) Solids—8 to 9%.

(a) Organic constituents

Protein—7.5% (Serum albumin, serum globulin, fibrinogen, prothrombin etc.).

Non-protein nitrogenous subtsances (NPN)—These are urea, uric acid, creatine, creatinine, ammonia, amino acids etc.

Fats—Neutral fats, phospholipid, cholesterol.

Carbohydrate—Glucose mainly.

(b) Inorganic constituents

0.9%. These are potassium, sodium, calcium, magnesium, phosphorus, iron, copper etc.

FUNCTION OF BLOOD

The function of blood is described below :—

(1) *Transport of nutrition*—Blood carries nutritive materials from one place of the body to the other place. It carries

digested food materials absorbed from the intestine to the various tissue cells for utilisation.

(2) *Acting as a vehicle*—It acts as a vehicle through which vitamins, hormones and other essential chemicals are transfered to their places of activity.

(3) *Drainage of waste products*—Waste products are carried to the organs of excretion i.e., kidney, lungs, etc.

(4) *Water balance*—It maintains the water balance of the body.

(5) *Maintenance of ion balance*—The blood helps to maintain ion balance between the cells and the surrounding fluids of various tissues.

(6) *Maintenance of acid-base equilibrium*—Blood has a power of buffering capacity through plasma protein and haemoglobin. It is maintained through the kidney, skin and lungs.

(7) *Defensive action*—The blood acts as a great defensive mechanism in various ways: (i) The white cells have phagocytic properties which engulf bacteria and foreign particles. (ii) Plasma proteins, help to develop antibodies which combat toxic agents.

(8) *Transport of respiratory gases*—Blood carries O_2 from the lungs to the tissues and CO_2 from the tissues to the lungs.

(9) *Act as a protein reserve*—The plasma protein of blood serves as a store house of proteins from which the tissue can draw its needs during starvation or inadequate protein diet.

ERYTHROCYTE OR RED BLOOD CORPUSCLES (RBC)

The shape of RBC in human is a circular, biconcave, non-nucleated disc. When viewed from the sides it looks like a dumb-bell. The size is 7.2μ (vide fig. 6).

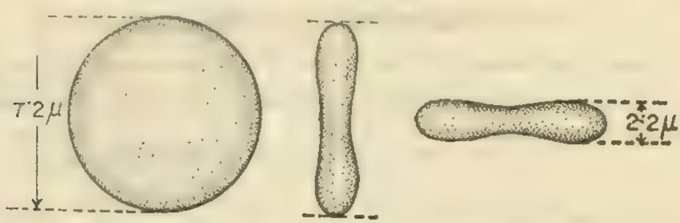


Fig. 6. Size and shape of RBC are shown schematically.

The normal average count in adult male is taken as 5 million per cubic millimetre of blood. In female it is about 4.5 million. After birth the bone marrow is the main site of erythrogenesis.

Stages of erythrogenesis are as follows: Haemocytoblast → Proerythroblast → Early normoblast → Intermediate normoblast → Late normoblast → Reticulocyte → Normal Erythrocyte.

HAEMOGLOBIN

Haemoglobin is the red pigment of blood. It is composed of two parts: (1) Globin (96%) is a specific simple protein. (2) Haem (4%) is a metalloporphyrin where the metal is iron. Mature RBC contains full of haemoglobin by replacing its nucleus.

Function of haemoglobin is mainly for transport of O_2. The iron part of haemoglobin combines with oxygen. CO_2 is also carried out by haemoglobin in the form of carboxyhaemoglobin.

Major part of CO_2 is carried out by plasma in the form of bicarbonate. Haemoglobin (Hb) usually increases during exercise in order to carry more O_2 to the tissues. Normal haemoglobin content of the blood is 14-16 gm/100ml of blood. In female, haemoglobin is slightly lower than male. When haemoglobin contents of blood decreases, anaemia develops. During heavy exercise a sudden rise of Hb is seen in blood which usually comes mostly from the spleen and this may be called as a store house of blood for emergency need.

WHITE BLOOD CORPUSCLES (WBC) OR LECOCYTES

The average total number of WBC is 6,000 to 8,000 per cu. mm. of blood. There are several varieties of WBC, each type possesses a characteristic morphology and staining property. These are classified into many types. Determination of the percentage of different varieties of leucocytes is known as the *differential count* of white blood corpuscles.

Classification of WBC

Granulocytes (Granular cytoplasm)	Lymphocytes	Monocytes
	1. Small } (25 to 30%) 2. Large	(5 to 10%)

1. Neutrophil (60 to 70%).
2. Eosinophil (1 to 4%)—Allergetic disease causes an increase of eosinophil percentage in blood.

3. Basophil (0 to 1%).

These are shown in (fig. 7).

Function of WBC is mainly for defence mechanism.

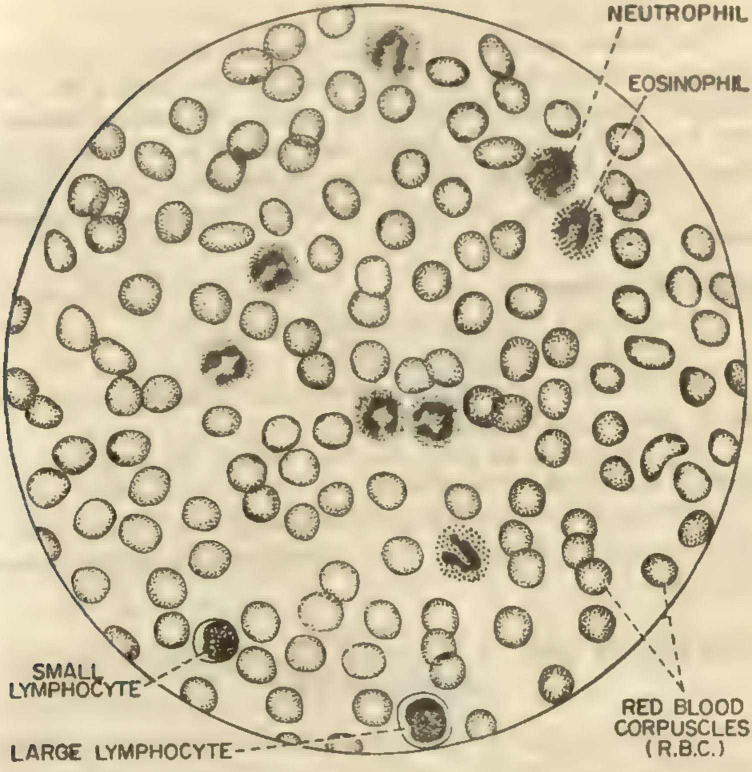


Fig. 7. Morphology of WBC showing different types.

BLOOD PLATELETS (THROMBOCYTES)

Platelets are non-nucleated round or oval, biconvex discs. The average size is 2.5μ. It helps in blood coagulation.

COMPOSITION AND FUNCTION OF LYMPH

Lymph should be defined as modified tissue fluid. Lymph is the clear watery appearing fluid found in the lymphatic vessels. A pure sample of lymph can be obtained by inserting a canula in the thoracic duct. After a fatty food, the lymph of the thoracic duct appears milky due to the presence of minute droplets of emulsified fats absorbed from tht alimentary canal. Usual colour is yellowish.

Composition of lymph

It contains large number of leucocytes (mostly lymphocytes). The composition is as follows :

1. Water—94%.
2. Solids— 6%.

The solids are the following : (1) Proteins—Total protein content is roughly half that of plasma. It is about 2 to 4.5%. Albumin, globulin and fibrinogen are found. Fibrinogen content is very low. (2) Fats—In fasting, fat content is low but is high usually after a fatty diet. (3) Carbohydrate—Sugar is found as high as 132 mgm/100ml. (4) Urea, creatinine, inorganic phosphorus, calcium etc.

Function of lymph

The functions of lymph are the followings :

(1) Drainage of excess tissue fluid.

(2) Nutritive—It supplies nutrition and oxygen to those parts where blood cannot reach.

(3) Absorption of fats—Fats are usually absorbed from the intestine through the lymphatics.

(4) Defensive—The lymphocytes found in lymph act as defensive cells of the body. The lymphatics also remove becteria from tissues.

COURSE OF CIRCULATION OF BLOOD THROUGH THE HUMAN HEART

The main fuctions of circulation of blood are to make available to the tissues its different metabolic needs. On the other hand it supplies oxygen and nutrients to the tissues and removes CO_2 and waste products from the tissues to the various locations viz. lungs, skin, kidney for elimination of it to the outside of the body. This mechanism is performed by the Cardio-Vascular system. The Cardio-vascular system includes heart, arteries, capillaries and veins.

The heart has got four chambers (fig. 8), i.e., two auricles and two ventricles. The two left chambers are separated from the two right ones with partitions. Aorta arises from the left ventricle which carries oxygenated blood to the various parts of the tissues. Pulmonary artery arises from the right ventricle which carries deoxygenated blood to the lungs for oxygenation and removal of CO_2. The oxygenated blood is returned from the lungs by the pulmonary vein to the left auricle and left auricle opens to the left

ventricle for supply of oxygen in different parts of the tissue. The right auricle receives all the venous blood from the body through

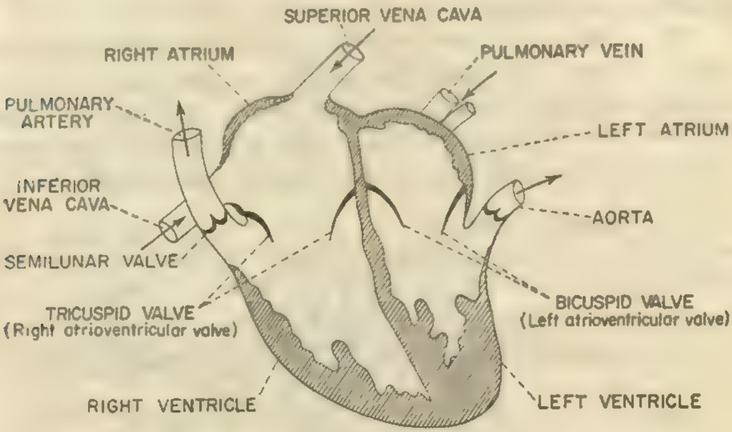


Fig. 8. Schematic representation of the chambers of heart.

three veins, i.e., inferior and superior venae cavae, and coronary sinus. The course of circulation is shown in the fig. 9 schematically.

Circulation is strictly one way. This is done by the action of valves. There are four sets of valves in the heart. These are: (1) tricuspid (right auriculoventricular opening), (2) mitral or bicuspid (left auriculoventricular opening), (3) *two* semilunar valves (left ventriculoaorta and the auriculopulmonary arteries). The circulations of blood through the cardiovascular systems are regulated by the pumping action of the heart. Heart beats 72/min in normal resting condition. During exercise heart beat increases maximally to 180-200/min in order to supply an increased demand of O_2. In each beat the heart pumps about 70ml of blood and this is known as stroke volume. The stroke volume also increases during exercises. The stroke volume times number of heart beats per min is known as *cardiac output* i.e., it is the amount of blood which is pumped out by each ventricle into the circulation per minute. This is also known as minute volumes of the heart. In adult cardiac output is about 5 litres/min. During exercise cardiac output increases to about 30 litres per minute.

Normally 5 litres of blood pass out per ventricle per minute i.e., 5 litres of blood flow through the tissue per minute and the same 5 litres of blood come back to heart per minute.

CONTROL OF THE CARDIAC OUTPUT

Cardiac output depends on the following factors: (a) venous return, (b) force of heart beat, (c) frequency of heart beats and (d) peripheral resistance.

(a) *Venous return*—Anything that increases or decreases the venous return, will alter the cardiac output accordingly. The vasomotor system adjusts the lumen of the arterioles and venules and thus alter the venous return. Rise and fall of blood pressure also adjust the return and thereby alter cardiac output.

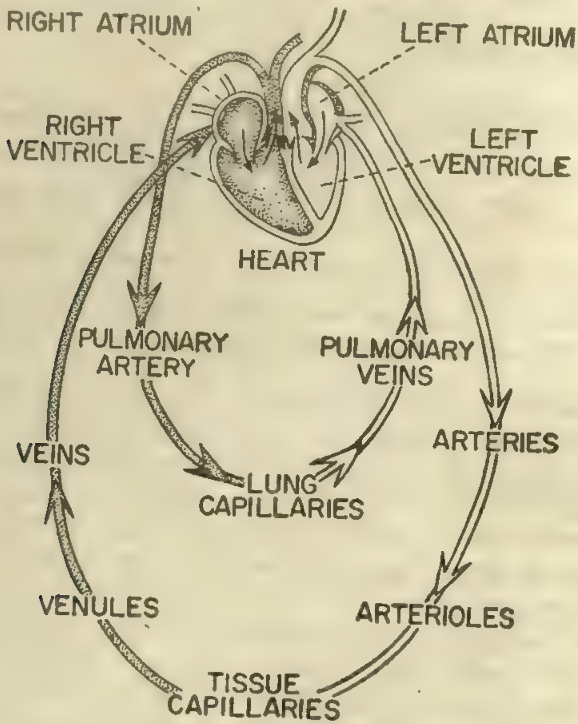


Fig. 9. Course of circulation through heart is shown schematically.

(b) *Force of heart beat*—The force of heart beat alters cardiac output. Greater the force of heart beat greater is the cardiac output.

(c) *Frequency of heart beat*—Cardiac output is increased by the increased frequency of heart beat.

(d) *Peripheral resistance*—General vasoconstriction of the arterioles will cause an increased peripheral resistance which decreases cardiac output.

METHODS OF MEASURING CARDIAC OUTPUT

Cardiac output could be measured by the Fick principle. It needs the following measurements: (a) Oxygen cousumption (ml/min) & (b) arteriovenous oxygen difference (per 100ml of blood). These are shown in the following way:—say.

(1) Total O_2 consumption/min = 200 ml.
(2) O_2% of arterial blood = 19 ml of O_2 per 100 ml blood
(3) O_2% of venous blood = 15 „ „ „ „ „
(4) Arteriovenous difference is therefore = 4 ml per 100 ml blood. (i.e., 19-15 = 4)

As each 100 ml of venous blood when passing through the lungs, takes away 4 ml of O_2, thus 200 ml of O_2 per minute will be carried away by how much quantity of blood could be worked out by the following formulla : i.e.,

$$\text{Cardiac output (ml/min)} = \frac{O_2 \text{ Consumption (ml/min)}}{\text{difference of } O_2 \text{ content in arterial and venous blood (ml. per 100 ml blood)}} \times 100$$

Then plotting the measured values, it could be shown that:

$$\text{Cardiac output} = \frac{200 \times 100}{4} = 5000 \text{ ml}$$

or *Cardiac output* = 5 litres/min.

BLOOD PRESSURE AND ITS REGULATION

Blood pressure is the lateral pressure exerted by flowing blood through the vessel walls. Blood pressure is measured in the following 3 names:—(1) *Systolic pressure*—The maximum pressure during systole or ventricular contraction. (2) *Diastolic pressure*—The minimum pressure during diastole or relaxation of ventricular muscles. (3) *Pulse pressure* is the difference between systolic and diastolic pressure which indicates the driving force of the heart. In athletes the pulse pressure is high which assists greater blood flow during exercise. During exercise all the pressure units increased to its maximal level to supply more blood to the muscles and thus helping in increase of cardiac output. In adult the Systolic is 120 mm Hg and Diastolic is 80 mm Hg and Pulse pressure is 40 mm Hg.

Physiologically blood pressure is measured by sphygmomannometer. The normal upper limits of systolic and diastolic pressures are placed at 140 and 90 mm Hg. respectively. It is achieved only

in old age. Physiological variations in blood pressure are mainly due to the following reasons :—e.g. age, sex, body built, exercise, posture, sleep, emotion or excitement etc.

Regulation of blood pressure

1. *Pumping action of the heart* :—The driving force of blood is mainly operated by the pumping action of the heart.

2. *Cardiac output* :—Cardiac output is regulated by the venous return, force and frequency of heart beat and thus controls blood pressure.

3. *Peripheral resistance* :—The main seat of peripheral resistance is the arterioles. Peripheral resistance depends on the followings : (a) velocity of blood, (b) viscosity of blood, (c) elasticity of arterial walls, (d) lumen of the blood vessels. Resistance is directly proportional to the first two and inversely to the last two factors. Thus blood pressure would be maximum if the peripheral resistance is high. In old age, the elasticity of arterial walls deteriorates and thus causes rise of blood pressure. In hypertension, the lumen of the arteriols forms major resistance by stiffness with the high cholesterol level of blood. In hypotension, the systolic pressure is below 100 mm Hg.

RESPIRATORY SYSTEM

The interchange of O_2 and CO_2 in the cells and in its surroundings in known as respiration. The process of respiration may be divided into two parts : internal and external respiration.

Internal respiration—The interchange of gases between the tissue cells and the surrounding fluid is known as Internal respiration.

External respiration—The interchange of gases between the circulating fluid and the external medium is known as external respiration. External respiration involves a special type of respiratory organ i.e., lung. In all air breathing vertebrates the organs of external respiration are the lungs which contain numerous air-sacs. These air-sacs are known as alveoli. Alveoli are surrounded by numerous capillaries in such a way tnat gaseous exchange takes place between aor in the alveoli and blood of the venous capillaries. The renewal of the air in the alveoli is governed by the movements of respiration (i.e., inspiration and expiration processes) and dynamic circulation of blood throhgh the capillaries. During inspiration O_2 is taken up by the blood capillaries from the alveoli and CO_2 is given off to the lungs from the blood. In subsequent expiration

CO_2 is washed out from the alveoli to the exterior i.e., in the atmosphere.

Structure of the Respiratory organ

The respiratory system includes the alveoli and a series of of passages i.e., airways. Nasal cavity opens to the trachea which has been subdivided into many branches (upto 23 in number). These are bronchi, bronchioles, terminal bronchioles, respiratory bronchioles, alveolar-duct, sac and then alveoli. Gaseous exchange

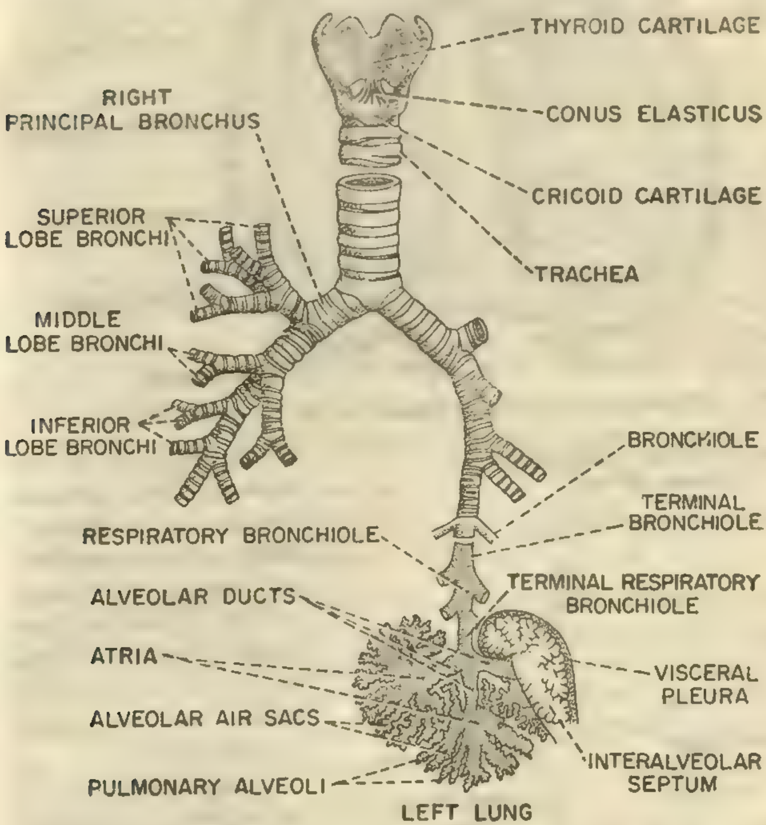


Fig. 10. Structure of the trachebronchial arrangement of the lungs.

takes place only in the alveoli by the process of gaseous diffusion. These are shown in fig. 10. The whole respiratory system is known as lungs. There are two lungs (left and right). Lungs are situated in the chest cavity i.e., within the thorax and these are shown in fig. 11:

Mechanism of inspiratory and expiratory movements

Inward flow of air is known as inspiration and outward flow of air is known as expiration. Inward and outward flows of air

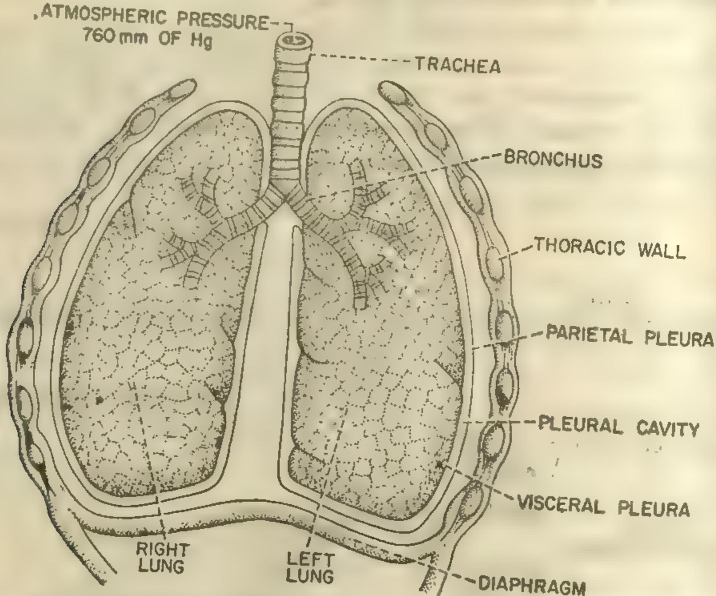


Fig. 11. Schematic representation of the lungs and thorax.

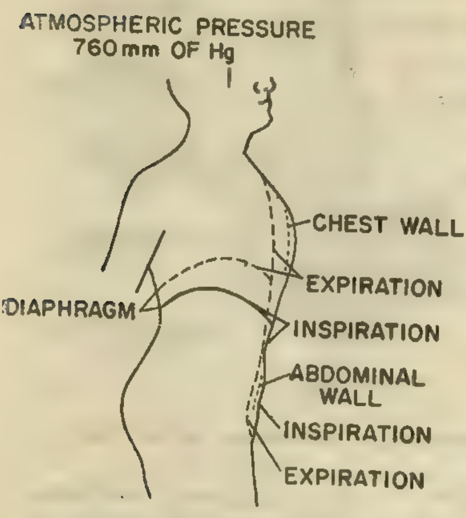


Fig. 12. Schematic representation of inspiratory and expiratory mechanism.

of the lungs are usually operated by changing the size of the thoracic cavity. It is a mechanical process which involves the contraction and relaxation of the various respiratory muscles during the two phases of respiration.

Inspiration is an active process. It involves the expansion of the chest cavity by downward movement of the diaphragm and thus there is an increase in the longitudinal length. The elevation of ribs increases

the anteroposterior diameter of the chest cavity by contraction of the intercostal muscles.

Expiration is a passive process. Expiration involves the upward movement of the diaphragm and thus causes a shortening of the chest cavity. There is also a depression of the ribs which causes a decrease of the anteroposterior diameter of the chest cavity. This is shown in fig. 12.

The physical principle which determine the respiration is the production of pressure difference in between the lungs and the atmosphere.

Due to physical law, air will flow from the higher to the lower pressure head.

During inspiration there is a fall of pressure in the alveoli below the atmosphere which causes rush of air entry. During expiration, alveolar pressure goes above the atmospheric pressure and thus air goes out. Thus the normal breathing may be called negative pressure breathing. This sequence of change of pressure is usually governed by intrapleural pressure which is subatmospheric. The chest wall and the lung wall are covered by thin layers which are known as parietal visceral and pleura respectively. The pressure between these two layers is called intrapleural pressure.

Muscles involved in respiration

The main muscles of respiration are : (1) diaphragm, (2) intercostal muscles and (3) abdominal muscles.

Diaphragm—It is a large dome shaped sheet of muscles which separates the thoracic cavity from the abdominal cavity. The contraction of diaphragm causes downward movement of the dome i.e., downward increase of the thoracic cage. There is a decrease of intrathoracic pressure with an increase of the abdominal pressure. Due to decrease of intrathoracic pressure air enters the lungs and thus causes inspiration. Diaphragm muscles are controlled by the phrenic nerve. Thus contraction of the diaphragmatic muscles causes its downward movement in order to operate inspiration. In quiet breathing expiration is a passive process. The diaphragm is pulled upward by the elastic recoil of the lungs and thorax which cause relaxation of the diaphragatic muscles in expiration.

Intercostal muscles—Contractions of these muscles cause an increase of the anterioposterior diameter of the thorax due to

elevation of anterior end of each rib and thus causes inspiration by upward and outward movements of the ribs. In expiration it is reversed i.e., when the inspiratory muscles cease to contract, it causes expiration by the elastic recoil of the lungs; and the thorax itself sinks by is own weight. The muscles are thus relaxed. Intercostal muscles are supplied by the intercostal nerves.

Abdominal muscles—These are the principal muscles which take part in forced expiration. These muscles have two important mechanical actions: (1) it raises the intra-abdominal pressure, (2) it draws the lower ribs downwards and medially. Abdominal muscles are inactive in normal expiration. It is operated only in the forced expiration. In forced expiration all these muscles are active. Diaphragm is pushed upward by the vigorous contraction of the abdominal muscles during forced expiration.

In inspiration, the intrathoracic or intrapleural pressure becomes more negative while in expiration it is less negative.

COMPARTMENTS OF LUNG AIR

Compartments of lung air are usually studied by spirometer

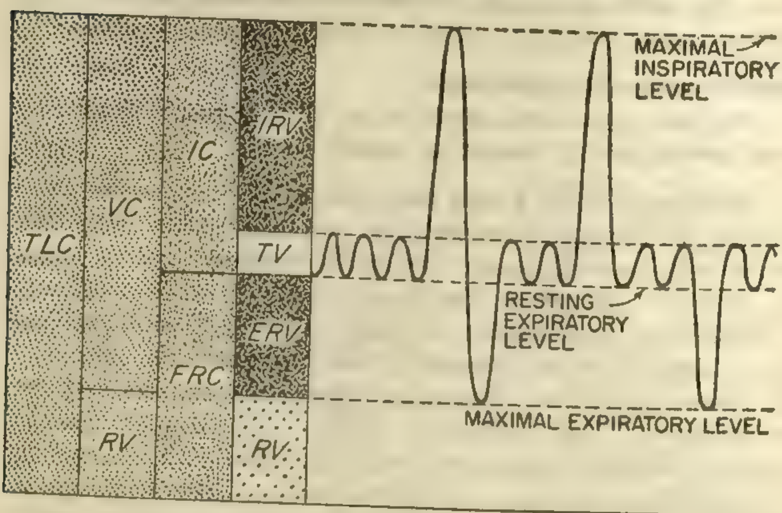


Fig. 13. Schematic representation of the compartments of lung air.

and these are divided into many parts or divisions by normal and various voluntary breathing maneuver. The different lung volumes

and the capacity of the lungs are known as compartments of lung air. These are shown in fig. 13.

(1) *Tidal volume* (*TV*)—It is the volume of air that involves inspiration or expiration in quiet breathing. The normal volume is 500 ml or 0.5 litres.

(2) *Inspiratory capacity*—(*IC*)—It is the volume of air which is usually taken up during maximum inspiratory effort following normal expiration. This volume is usually about 3.4 litres.

(3) *Expiratory reserve volume* (*ERV*)—It is the volume of air which can be breathed out by forced expiration following normal expiration. The volume is about 0.9 litres.

(4) *Residual volume* (*RV*)—It is the volume of air which remains in the lungs after maximal expiration. This air can only be expelled from the lungs by opening the chest wall and allowing the lungs to collapse. The average volume is about 1.3 litres.

(5) *Vital capacity* (*VC*)—It is the volume of air that can be breathed out by maximal forced expiration following maximal forced inspiration. The volume is about 4.3 litres. (average).

(6) *Functional Residual Capacity* (*FRC*)—It is the volume of air or gas remaining in the lungs after a normal expiration. This is the sum of RV and ERV. The volume is about 2.2 litres.

(7) *Total Lung Capacity* (*TLC*)—It is the volume of air that remains in the lung following maximal inspiration, i.e., vital capacity plus residual volume or FRC+Inspiratory capacity. It is about 5.6 litres.

RV, FRC and TLC cannot be measured with only spirometer, as RV is obtained by an indirect way in man. RV is usually measured by helium or nitrogen equlibrium technique or by wash out of N_2 from the lungs with O_2. In various lung diseases the RV & FRC increase. The tests of these different lung volumes and capacities are known as lung function test.

Maximum breathing capacity

The most important lung function is the maximum breathing capacity. In short it is symbolized as MBC. It is the amount of air which can be breathe as swiftly as possible with both fast rate and greater depth of breathing for a period of 15 sec in a Douglus bag through one-way valve in the mouth by closing the nose. It is expressed as per min by calculation. Normal MBC varies from

100 to 150 L per min. In asthma, emphysema and fibrosis, the MBC becomes too low even it may be below 50 L/min.

COMPOSITION OF INSPIRED, EXPIRED AND ALVEOLAR AIR

Inspired air is the atmospheric air which contains O_2 in greater amount than expired air as O_2 is absorbed by the blood capillaries in the alveoli. In reverse CO_2 content of the expired air is greater than the inspired air as CO_2 diffuses out from the blood to the alveoli which in turn comes out as an expired air. The nitrogen is an inert gas it does not take part in gaseous exchange in the lungs and thus remaining same. But actual measurements of expired air shows a slightly greater value of nitrogen which is due to unequal CO_2 and O_2 diffusion in the alveoli i.e., CO_2 production in the lungs is less in comparison to O_2 absorption and thus inspired volume shrinks and increases the N_2 concentration in the subsequent expiration. The respiratory quotient (RQ) is normally about 0.90 and is measured in the following way:

$$RQ = \frac{\text{Volume of } CO_2 \text{ output/min}}{\text{Volume of } O_2 \text{ uptake/min}}$$

e.g., in normal resting condition,

$$RQ = \frac{180 \text{ ml}}{200 \text{ ml}} = 0.90$$

i.e., 90 ml CO_2 comes out in expiration when 100 ml O_2 is absorbed in the lungs. RQ increases to 1 or more than 1 during exercise. O_2 uptake may be increased to 2-4 litres/min during maximal work or exercise. This O_2 uptake is usually greater in Western than Indian.

The composition of alveolar air is also different from expired air as some portion of the inspired air remains within the dead space and is known as VD (volume of dead space). Air remaining in the conducting passage of trachea, bronchi and bronchioles does not take part in gaseous exchange and thus its composition remains same as the composition of inspired air. This passage is also known as airway which is not supplied by any blood capillaries. Thus volumes of alveolar air (VA) and VD constitute the expired air. Due to this fact alveolar air contains more CO_2 and more N_2 and less O_2 in comparison to those of expired air. The VD is about 150 ml, when tidal volume is normal, i.e., about 500 ml.

The comparisons of inspired, expired and alveolar air are shown in the following way : (vide table 5).

TABLE : 5.

Comparative composition of air (in normal resting state)

Gases	Inspired air %	Expired air %	Alveolar air %
Oxygen	20.93	16.40	14.50
Carbondioxide	0.03	4.00	5.50
Nitrogen	79.04	79.60	80.00

Compositions of expired and alveolar air vary from individual to individual. These also change usually during exercise and varied environmental conditions.

3

NEUROPHYSIOLOGICAL CONTROL OF BODY

(General classification of receptors. Structure of Neurone, Synapse and Motor end plate. Reflex action. Central, Peripheral and Autonomic nervous system.)

RECEPTORS

The nervous systems of higher animal and man are very complex processes which involve more units to function at a time to cope with the external environment. This is a stimulus—response mechanism for a better coordination between the different organisms. The unit of the nervous system is known as neurone which carry impulses from the sensitive regions called receptors. In other

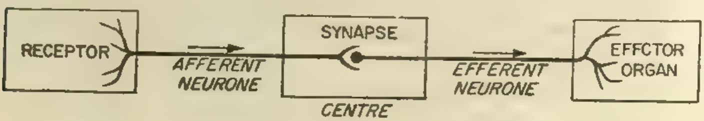


Fig. 14. Schematic pathway of receptor's action.

words receptor is a sensitive region of the nervous system which carrys impulse from its surroundings and sends it to the effector organs through afferent nerve fibre (toward centre) to the centre where this sensory stimulus is converted into a motor impulse. This impulse passes through the efferent (away from the centre) or motor nerve fibre to the effector organs and thus causes contraction and relaxation of the muscles or may activate a glandular cell causing it to secrete for various physiological functions of the body. This behaviour of the receptor is known as reflex mechanism and this is shown in fig. 14.

Classification of receptors

Receptors may be divided into two divisions mainly. These are: (1) Exteroceptors, and (2) Interoceptors.

Exteroceptors are stimulated by the change of external environment and thus transmit the external stimuli to the internal part of the body to make the response accordingly. These may be *contact receptors* e.g., touch on skin, and *distant receptors* e.g., smell by nose, sight by eyes and sound by ear. *Thermoreceptors*

(heat and cold) and *pain receptors* (in skin) are also belonged to the exteroceptors.

Interoceptors are stimulated by the interior environment of the body. This may be divided into three main receptors. These are : (1) Proprioceptors, (2) Labyrinthine sense organs and (3) Visceroceptors.

Proprioceptors—These are located in the muscles, joints and tendons. These are stimulated by stretch and contraction of the muscles. These receptors are thus intimately concerned with reflex muscular activity and may help in locomotion and posture.

Labyrinthine sense organs or receptors—Bending the neck backwards causes increased tonus of the fore limbs with reduction of tone of the hind limbs. These reflexes are best studied on decerebrate cats with intact labyrinths.

Visceroceptors—These receptors are present in the internal organs of the viscera i.e., lungs, heart, cardiovascular system, intestine, kidney etc. These may be mechanoreceptors and chemoreceptors. The various receptors have been discussed in the following headings :—

1. **Pulmonary receptors**—There are three types of pulmonary receptors. These are : (a) Pulmonary stretch receptors, (b) Irritant receptors and (c) Type J receptors.

Stretch receptor is stimulated by the stretch of the lung during inspiration. These may be present in the bronchioles or alveoli. *Irritant* receptors are present in trachea and airways and these are stimulated by mechanical irritation which may be brought about by mucus or dust or other particles. *Type J receptors* may be present close to the pulmonary capillaries i.e., within the interstitial fluid which is usually stimulated by the rise of pulmonary capillary pressure. All the pulmonary receptors mediate through vagus nerves. These receptors are concerned with the control of respiration.

2. **Cardiovascular receptors**—These are the following types :—

(a) Aortic baroreceptors : These receptors are located on the aortic arch and these are connected with aortic nerves. Baroreceptors are also present in the carotid body. These are stimulated by a rise of blood pressure which causes stretch of the receptors. It controls blood pressure.

(b) *Atrial receptors*—These are present in the atrium and is stimulated by rise of blood pressure.

(c) *Ventricular receptors*—The receptors are present in the

ventricles and these are stimulated by ventricular contraction. It controls heart.

(d) *Chemoreceptors*—These receptors are situated in the aortic and carotid bodies and these are stimulated by the chemical composition of blood e.g., CO_2, O_2 and H^+ of blood. It controls respiration.

3. **Esophageal receptors**—These are situated in the esophagus and may be called mechanoreceptors. It is stimulated by distension during swallowing of food. It is mediated through vagus nerve endings.

4. **Gastrointestinal receptors**—It is situated in the gastro-intestinal tract. These are known as mechanoreceptors.

5. **Gastric stretch receptors**—It is situated in the stomach and is stimulated by distension of the stomach by entry of food or water.

Function and properties ef receptors

Receptors behave like transducer and transmit any type of physical energy into an electrical energy. Transducer is a mechanism which transforms one kind of energy into another. The receptors stimulate nerve endings and propagate impulses into an electrical signal in the respective nerves. These produce action potential. Frequency discharge of action potential is usually measured and it is proportional to the magnitude of the applied stimuli in the receptors.

Properties of the receptors are the following:

(1) *Specificity*—Each receptor is sensitive to a specific stimulus and evokes only specific sensation.

(2) *Relation with the intensity of stimulus*—Sensation becomes more intense as strength of stimulus is increased.

(3) *Intensity discrimination*—The magnitude of the sensation is proportional to the log of the intensity of stimulus.

(4) *Recruitment*—When the strength of stimulus is increased a large number of receptors are recruited.

(5) *Adaptation*—When a sensory organ (receptor) is stimulated for some time the frequency of discharge is gradually decreased as decay curve. The phenomenon is known as adaptation. There are slowly and rapidly adapting receptors.

(6) *Threshold*—Each receptor has a threshold for stimulation. The minimum intensity which requires to stimulate receptors is known as threshold of stimulus.

STRUCTURE OF NEURONE, SYNAPSE AND MOTOR END PLATE

The unit of the nervous system is the neurone. Structure of the neurone is shown in fig. 14A. Neurone is made up of nerve cell and its processes called nerve fibres. Dendrites or dendrons

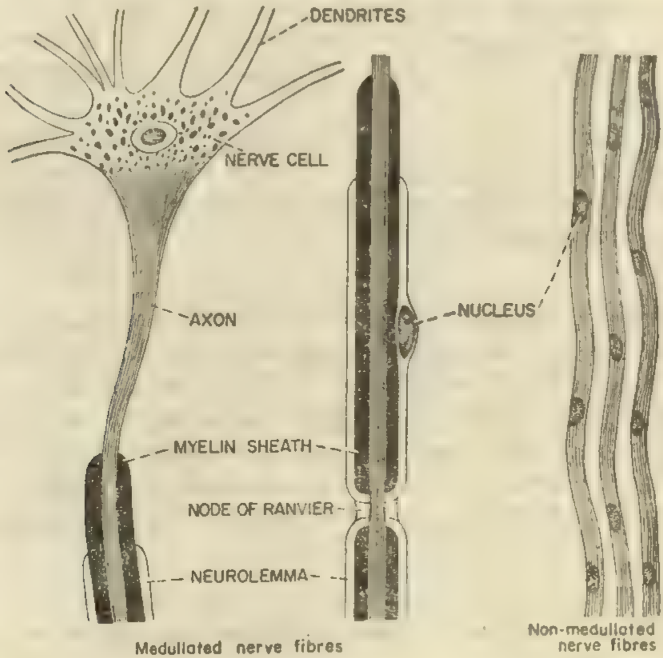


Fig. 14A. Structure of the neurones.

are known as receptive processes. The discharging process is known as axon. The axon constitutes the nerve fibres. Nerve fibres are of two types: (a) medullated and (b) non-medullated.

Medullated (Myelinated) fibre is composed of three elements. These are axis cylinder, myelin sheath and neurolemma. Axis cylinder contains large number of nerve fibres as a direct continuation of the protoplasm of the nerve cell. Myelin sheath is a white covering of the nerve fibres. The axon is at first enveloped by the Schwann cell which in turn is surrounded by multilayered membrane called myelin sheath (medullary sheath). Its function is to insulate the nerve fibres. All nerve fibres outside the central nervous system receive another homogeneous nucleated covering called neurolemma. Its function is to protect the nerve fibres and

it is essential in regeneration of damaged peripheral nerves. At regular intervals the peripheral nerve fibre possesses constriction called nodes of Ranvier where medullary sheath is absent. Branching of the nerve fibre usually takes place at this node. That portion of the two adjacent nodes is called internode and it possesses schwann's cell with an oval nucleus under the neurolemma.

Non medullated (Amyelinated) fibres are composed of two elements. These are the central axis cylinder and the neurolemma. The post ganglionic fibres of the autonomic nervous system belong to this type.

The function of the neurone is to receive impulses from a receptor or from the sensory nerve endings. The impulse is then transmitted to the centre or synapse to cause an effective changes in the effector ogans.

Synapse

Synapse is the junctional region where one neurone ends and the other begins. The terminal branch of the axon of one neurone comes in contact with dendrites of another. Thus the junction of presynaptic cell and the post synaptic cell is known as synapse. Many presynaptic neurones may end or converge on any single post synaptic neurone and the axon of any presynaptic neurone may be branched and this may diverge to end on multiple post synaptic neurones.

Types of synapses

Synapses are of three types according to their nature of connections. These are :—

(1) *Axosomatic synapse*—The presynaptic terminal of the axon may end in the cell body of the neurone. Synaptic connections between the basket cell and the Purkinji cells in the cerebellum are of axosomatic type.

(2) *Axodendritic synapse*—The presynaptic fibres of any axon end in the dendrites of the postsynaptic cell e.g., cerebellum.

(3) *Axo-axonic synapse*—Presynaptic fibres of any axon ends in the axon of the post synaptic cells.

Structure of synapse

Under electron microscope it is seen that presynaptic fibres end in the expanded terminal known as the synaptic knob. The synaptic knob and the soma (cell body of the neurone) have an intact membrane. The synaptic knob is separated from the soma of the post synaptic cell by a synaptic cleft (gap). Glial membrane covers

the outer side of the synapse. The synaptic vesicles are more concentrated towards the synaptic cleft. The synaptic vesicles contain the excitatory transmitter materials that mediate transmission of nerve impulses from the presynaptic neurone to the post synaptic

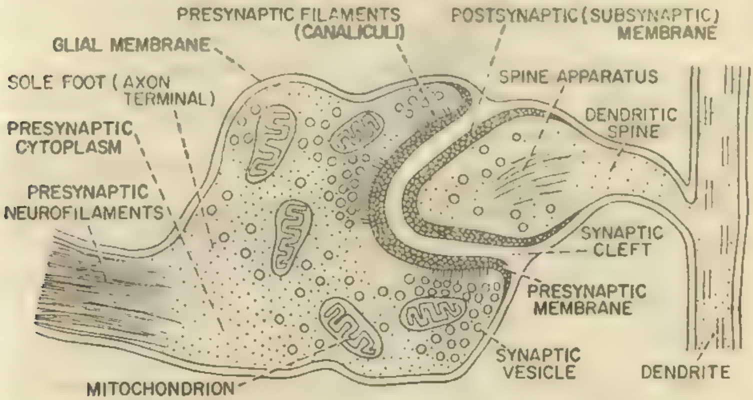


Fig. 15. Electron microscopic representation of an axodendritic synapse.

neurone. It is belived that mitochondria helps in synthesis of transmitter substances. Electron microscopic structure of synapse are shown in the fig. 15.

The transfer of information across a synaptic junction is called synaptic transmission which are brought either by chemical or by electrical or by both processes. The main function of the synapse is the transmission of nerve impulses from one end to other end.

Structure of the motor end plate

The motor nerve when ends into the muscle fibre loses its myelin sheath and it branches into several structures and these are known as axon terminals. This neuromuscular junction or myoneural junction is known as motor end plate (fiig. 16). The axon terminals lie within the corrugated sarcolemma i.e., the junctional folds of the muscle fibre. The corrugated sarcolemma is formed by the numerous invaginations of the sarcoplasm and is known as synaptic gutter. There is a gap in between the axon membrane and the sarcolemma and this is known as synaptic cleft. Synaptic cleft is filled with extracellular fluids. The whole axon terminal is covered by the cytoplasm of the Schwann cell. Numerous muscle nuclei are also shown in the sarcoplasm.

Under electron microscope the axon terminal or sole foot shows the presence of many mitochondria, numerous vesicles and it is

covered by the cytoplasm of the Schwann cell. It is claimed that mitochondria of axoplasm takes part in the synthesis of acetylcholine i.e., the excitatory transmitter substance of neuromuscular junction.

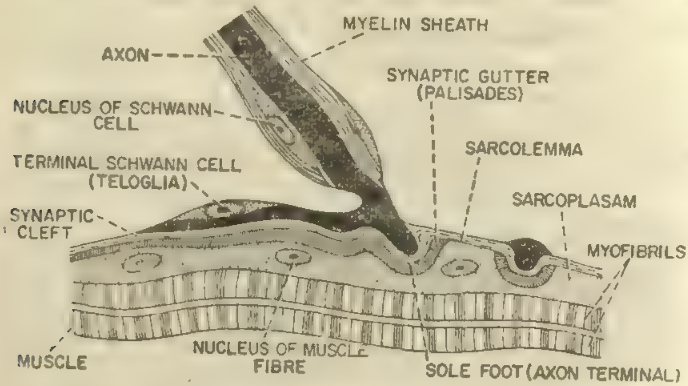


Fig. 16. Motor end plate is shown as neuromuscular junction.

The acetylcholine is usually stored in the vesicle and released when the propagated impulse reaches the post junctional membrane. Function of motor end plate is to trigger an action of muscle fibre.

REFLEX ACTION

Reflex action is an involuntary effector or motor response to an application of a sensory stimulus e.g., if the hand touches a

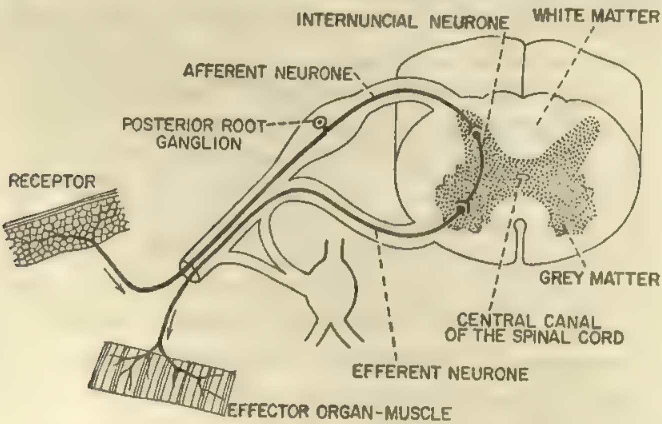


Fig. 17. Complete pathway of reflex action in the spinal cord.

hot surface it is withdrawn immediately. This phenomenon is governed by the reflex action.

Reflex actions are of two types: (1) Unconditioned or Inborn reflex (inherent) and (2) conditioned reflex (acquired).

The complete pathway of reflex action is known as reflex arc. This comprises four parts: (a) Afferent limb (receptors or sensory nerve fibres), (b) Centre (where the sensory stimulus is converted into a motor impulse), (c) Synapse (Communicating link of two neurones), and (d) Efferent limb (consists of motor nerve fibres which ends in the effector organ e.g., muscles). The reflex arc is shown in fig. 17.

General characteristics of reflex action

Some characteristics of reflex actions are discussed in the following headings :—

1. *Delay*—The short interval between the application of stimulus and the onset of reflex response is known as delay or latent period.

2. *Summation*—If a number of subminimal stimuli be applied, their effects will be summated to produce greater response.

3. *Fatigue*—If a particular reflex be repeatedly excited at frequent intervals, the response becomes progressively feebler and finally disappears and this is called fatigue.

4. *Reciprocal innervation*—In a reflex mechanism when some group of muscles contract, the antagonistic group of muscles relax to the same degree.

Central, Peripheral and Autonomic Nervous system

The nervous system of human body is highly developed and it may be divided into three parts. These are: (1) Central nervous system, (2) Peripheral nervous system and (3) Autonomic nervous system (Sympathetic and Parasympathetic).

CENTRAL NERVOUS SYSTEM

The central or somatic nervous system consists of two parts. These are: (1) Spinal cord (situated inside the vertebral column) and (2) Brain (situated inside the cranial cavity i.e., skull).

SPINAL CORD

The spinal cord lies losely within the vertebral column. This is cylindrical in shape. It is made up of a series of superimposed segments, from each of which a pair of nerve roots arises. Each segment of the spinal cords gives rise to dorsal and ventral roots together form a single pair of nerves. The spinal cord is divided

into 31 segments. It is composed of 8 pairs of cervical, 12 pairs of thoracic, 5 pairs of lumber, 5 pairs of sacral and 1 pair of coccygeal nerves.

The spinal cord is a primary centre of reflex action. It consists of the main conducting paths to and from higher centres. The spinal cord may be considered as consisting of more or less autonomous segments. Each segment contains afferent nerves. The nerve fibres carrying different sensations enter the spinal cords through the posterior roots. Inside the cord, a rearrangement takes place i.e., fibres carrying one kind of impulse tend to collect into

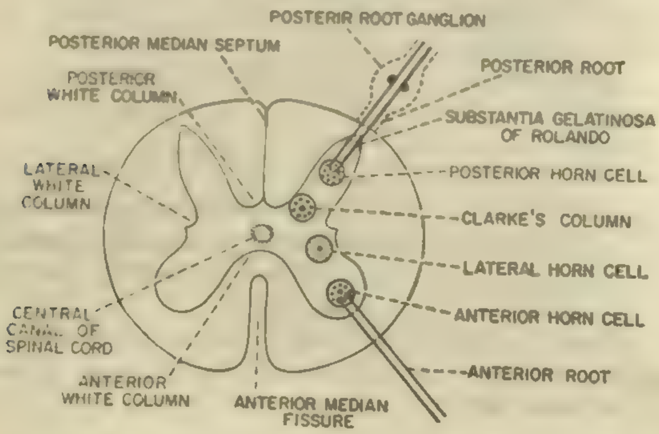


Fig. 18. The structure of spinal cord is shown schematically.

a bundle and it is called sensory tracts or ascending tract. Similarly motor or descending tracts from the centres come through the anterior root of the spinal cord. Ascending tract carries impulse of stimulus to the brain from the sensory nerve ending and descending tract carries impulse from the brain to the effector organ.

There are many ascending and descending tracts in the spinal cord.

Fibres carrying pain, temperature and crude touch terminate round the posterior horn cells. The second order of neurone arises from this posterior root and passes out as the spinothalamic tract within the spinal cord. Before terminating in the posterior horn the pain and temperature fibres constitute the so called tract of Lissauer.

Some fibres pass directly to the anterior horn cells and establish various reflex arc locally i.e., knee jerk etc.

The pyramidal tract is known as descending tract which convey motor impulse to the spinal cord for controling the voluntary movement (fingers and hands for subserving skill work) from the higher centres in the brain.

Structure of the Spinal cord—The structure of the spinal cord is given in fig. 18. It consists of central canal, gray matter and white matter.

Spinal cord is symmetrically divided into two lateral halves by septum. The dorsal septum is known as posterior median septum. The ventral septum is called anterior median fissure having cleft or fissure. The brief histological structure are the following:

Central Canal—The Central cannal is situated in the middle part of spinal cord which is lined by cubical ciliated epithelium (ependyma). Cerebrospinal fluid (CSF) circulates through this canal. The Central canal is surrounded by gray matter and forms isthmus.

Gray matter—Gray matter on each half consists of three parts: anterior horn, lateral horn and posterior horn. Gray matter is composed of nerve cells, neuroglia and nerve fibres.

(a) *Nerve cells*—These are anterior, posterior and lateral horn cells. The anterior nerve root takes origin from the anterior horn cells (for motor function).

(b) *Posterior horn* cells are relay station for posterior nerve root which sends impulse to the spinocerebellar tract.

(c) *Lateral horn cells*—These are relay station for autonomic nervous system. It is found only in the thoracic and upper lumber regions. They give preganglionic sympathetic fibres and come out through the anterior spinal root.

White matter—Gray matter is surrounded by the white matter consists of myelinated and unmyelinated fibres. These are divided into anterior, posterior and lateral white column. It possesses no cells and is occupied by the various ascending, descending and transversed fibres.

BRAIN

Brain is shown in fig. 19. This may be divided into fore, mid and hind brain or Prosencephalon, Mesencephalon and Rhombencephalon.

Prosencephalon is known as fore brain and it consists of the following parts: (a) Telencephalon and (b) Diencephalon.

Telencephalon possesses the following parts: (1) Cerebral hemisphere, (2) Corpus striatum, (3) Internal capsule and (4) Corpus callosum. Diencephalon contains:—

(1) Thalamus, (2) Hypothalamus and (3) Geniculate bodies.

Mesencephalon is known as mid brain and it is divided into two parts: (1) Corpora quadrigemina and (2) Cerebral peduncles.

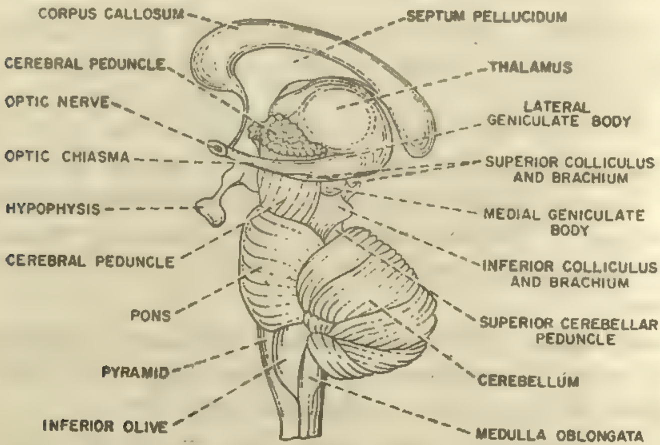


Fig. 19. Various parts of the human brain.

Rhomboncephalon is divided into Metencephalon and Myelencephalon. These are also known as hind brain.

Metencephalon consists of:

(1) Pons, (2) Cerebellar peduncles, and (3) Cerebellum. Myelencephalon is known as Medulla oblungata.

Cerebral cortex

The highest portion of the central nervous system is the cerebral cortex. It behaves as a higher reflex centre of vastly greater capacity for mediating complex activity by virtue of many information it may receive and the large motor apparatus over which it presides. It is a seat of consciousness and it acts as a store house of memory. It is also the centre of volition activity. It is covered outwardly with gray and inwardly with white matter.

Each hemisphere has five main lobes and four main fissures. The lobes are: (1) Frontal, (2) Parietal, (3) Occipital, (4) Temporal and (5) Limbic area. It is shown in fig. 20.

The cerebral cortex shows both axons and dendrites of various nerve fibres. Pyramid or Betz cell constitutes the pyramidal tracts.

In the cortex, chains of neurones may be activated in a cyclical or reverberating fashion and thus possibly constitutes the morphological basis of memory.

The occipital lobe is associated with vision. The different areas of the cortex are responsible for controlling various functions as a higher centre. Hearing is associated with the region of temporal lobes. The large area in the parieto-temporal-occipital region is concerned with speech. A large area on temporal lobe evokes

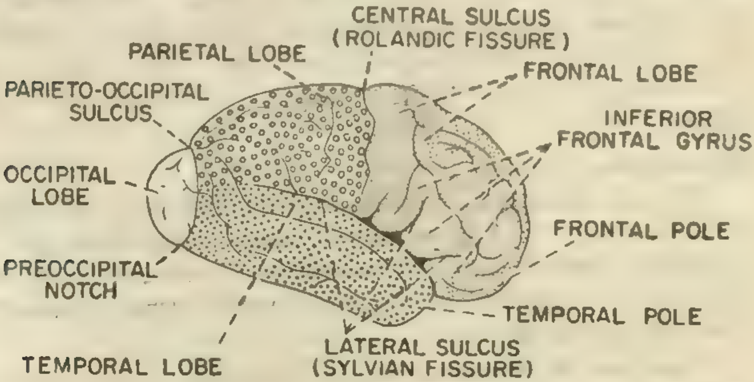


Fig. 20. Cerebral cortex with its various parts.

awareness of past experience and is called Penfield interpretative area. Anterior part of the frontal lobe is the seat of intelligence. Prefrontal lobes helps in complex intellectual performance i.e., gives judgement (or working out of mathematical problems). Stimulations of these lobes alter heart rate, blood pressure and respiration. Parietal lobe helps to understand the complete meaning of a particular sensation. Limbic lobe controls the emotional reaction, behavioural changes, motivation etc.

Functions of the cerebral cortex

Functions of the cerebral cortex are as follows:

(1) It has a tonic inhibitory control over lower motor centres. (2) It is the seat of the conditioned reflex. (3) It helps in perception of touch, pain, heat, cold and kinesthetic sensations. (4) It controls the special senses such as taste, smell, vision, hearing etc. (5) It is responsible for memory, intelligence, planning, judgement etc.

The functional changes of the cerebral cortex may be studied by noting the electrical activity and is known as Electroencephalogram (EEG). In human subjects four types of waves, are found

and these are alpha, beta, theta and delta. During deep sleep alpha wave disappears. Delta waves are seen during deep sleep.

Thalamus

The thalamus is a large collections of nerve cells at the top of the midbrain and it is a lower part of the forebrain.

Thalamus is an important reflex centre. It is the great relay station for pathways coming from cerebellum, cerebral cortex and the peripheral sensory system. It functions as a crude sensation. The emotional reactions are mediated through thalamus. Thalamus also connects the reticular complex or nucleus which receives impulse from the lower centres and relay impulse to the cerebral cortex.

Hypothalamus

It is the basal part of the diencephalon and is situated below the thalamus. The hypothalamus is the highest centre for the autonomic nervous system. It has got a closed connection with the hypophysis and is thus concerned with a complex neurohormonal regulatory apparatus.

Functions of hypothalamus are discussed in the following headings :—

(1) It controls sympathetic nervous system.
(2) It controls parasympathetic nervous system.
(3) It regulates body temperature.
(4) It controls emotional reaction.
(5) It acts as a feeding and thirsting centre.
(6) It controls sleep and sexual function.
(7) It regulates pituitary centre.
(8) It regulates cardiovascular system e.g., heart rate, blood pressure, circulation etc.
(9) It helps in secretion of gastric juice.

Midbrain (Mesencephalon)

The midbrain connects the forebrain with the hindbrain. It is the important correlation centres and is concerned with motor coordination. Ventral part is called cerebral peduncles and unites with the pon. Dorsal part is called the corpora quadrigemina (superior colliculi). The superior colliculi are responsible for visual reflexes and it reflexly alters the position of the trunk, head, eyes and limbs in response to retinal impulses by means of the tectospinal tract.

Pons varoli

It is a thickening part above the medulla oblungata. Pons is primarily concerned with the maintenance of normal rhythm of respiration.

Cerebellum

Cerebellum is the largest part of the hind brain. It lies behind the pons and medulla oblungata. It is divided into main three parts: (a) archicerebellum, (b) palaeocerebellum & (c) neocerebellum. These are functionally different from each other.

It usually acts as a feed back centre in between the cerebral cortex and peripheral motor movements i.e., initiation takes place by the cerebral cortex and the cerebellum regulates them.

The main function of the Cerebellum is the control of movement, posture and motor tone of the various muscles.

Medulla oblungata

The cervical spinal cord is expanded conically to form medulla oblungata as a part of the hind brain. In the medullary reticular formation, the respiratory centres are situated which control respiration. Cardiac and vasomotor centres are situated near the dorsal nucleus of the vagus which control the cardiovascular system. Disturbances in the medulla oblungata may lead to death from respiratory and cardiac arrest. The various cranial nerves are situated in the medulla oblungata such as VII, IX, X, XI and XII. The vagus nerve is known as Xth while glossopharyngeal nerve is called IXth cranial nerve.

PEREPHERAL NERVOUS SYSTEM

Spinal nerves and the cranial nerves are the peripheral nervous system. There are 31 pairs of spinal nerves and 12 pairs of cranial nerves. Both spinal and cranial nerves constitute the autonomic nervous system and it would be discussed in separate heading.

Spinal nerves

All the spinal nerves are mixed nerves functionally as it contains both motor and sensory fibres. Morphologically, each nerve consists of somatic and visceral fibres.

The somatic fibres are both afferent and efferent. The somatic afferent arises from the posterior root ganglion and carries sensations from the skin and other somatic structures to the spinal cord.

The somatic efferent fibres arise from the anterior horn cells and innervate the somatic muscles.

Visceral fibres belong to the autonomic nervous system and these consists of both afferent and efferent fibres which are concerned with the innervation of viscera.

Cranial nerves

There are 12 pairs of cranial nerves. These arise from the various parts of the brain stem. The function of the cranial nerves are as follows :—

Function

Cranial I, olfactory, gives sense of smell.
" II, optic, gives visual sensation.
" III, oculomotor, helps in movement of eye ball.
" IV, trochlear, causes movement of eye ball.
" V, trigeminal, moves mandible and causes also tactile sensibility of skin.
" VI, abducens, causes lateral movements of the eye balls.
" VII, facial, controls facial movement, sensation of taste and secretion of saliva.
" VIII, vestibulocochlear, controls hearing.
" IX, glossopharyngeal, controls sensation for taste, proprioception.
" X, vagus, causes various sensation, gastric secretion, it is also involved in visceral reflexes for heart and lung.
" XI, spinal accessory, controls movements of head and shoulder.
" XII, hypoglossal, controls movements of tongue.

AUTONOMIC NERVOUS SYSTEM

Autonomic system is that part of nervous system whose actions are generally unconscious and independent of will. Certain centres of medulla, pons, midbrain and other higher centres like hypothalamus, thalamus, corpus striatum and cerebrum also control this system. Cerebrum controls very little and it is mostly involuntary in action.

Autonomic nervous system can be classified into three ways :—(1) Anatomical, (2) Functional and (3) Chemical.

Anatomical classification—These are craniosacral (III, VII, IX, X and sacral 2-4) and thoracolumber (thoracic 1-12 and lumber 1-3). The former is called parasympathetic and the latter is known as sympathetic.

Functional classification—It is classified according to the nature

of function. These are sympathetic as thoracolumber and parasympathetic as craniosacral. These two nerves are functionally opposite and control the activity of viscera e.g., parasympathetic activity causes slowing of the heart rate while sympathetic activity increases the heart rate.

Chemical classification—According to the secretion of chemical substances these are of two types: (1) Adrenergic (sympathetic) and (2) Cholinergic (parasympathetic).

The adrenergic fibres secrete epinephrine or norepinephrine at the nerve endings while cholinergic fibres produce acetylecholine both at the nerve endings and synapses.

Autonomic nervous system are very important to control the viscera by reflex action. Like some of the somatic reflex arcs the autonomic reflex arc also consists of three neurones, i.e. afferent, connector and efferent neurones. The connector neurone of autonomic nervous system lies in the lateral horn cells unlike somatic where this is found in the posterior horn cells. In the somatic system the effector neurone is situated in the anterior horn cells but in autonomic system this is not present in the central nervous system at all and this lies in the form of ganglion outside the central nervous system. Thus the *presence of peripheral ganglia is the characteristic feature of the autonomic system.*

In the sympathetic system the ganglia lie away from the viscera supplied but in the parasympathetic system they lie in or near the viscera usually. Thus the parasympathetic system exert more localised action than the sympathetic system. Autonomic reflexes are mostly of polysynaptic in nature. As the interneurone located in the spinal cord the integrity of the spinal cord is essential for the regulation of the autonomic reflex arc.

Function of Autonomic Nervous System

The autonomic nervous system maintains constancy of the internal environment of the body i.e. called homeostasis. It maintains the vital processes of the body e.g. circulation, digestion, secretion and excretion through the reflex responses by their two wings i.e. sympathetic and parasympathetic mechanisms. As most of the organisms are supplied both by sympathetic and parasympathetic nerves, the effects of the two, as a rule, are antagonistic to each other. Thus the function is also opposite usually. The main functions of sympathetic nervous system are the followings:

(1) Dilatation of pupils in eye.
(2) Acceleration of the heart beat.

(3) Inhibition of movements and secretion of intestine.
(4) Constriction of cutaneous blood vessels.
(5) Increase of blood pressure.
(6) Contractions of urinary and rectal sphincters.

The function of the parasympathetic nervous system are just opposite of the above functions i.e.

(1) Constriction of the pupils in eye.
(2) Slowing or inhibition of heart beat.
(3) Stimulation of movements and secretion of intestine.
(4) Cutaneous vasodilatation.
(5) Lowering of blood pressure.
(6) Relaxation of urinary and rectal sphincters.

Most of the organs in the human body are supplied both by sympathetic and parasympathetic nerves and thus exert antagonistic actions. But adrenal medulla, most arterioles, uterus etc. are supplied by sympathetic nerve only. Oesophagus, gastric glands, pancreas, islets of Langerhans and lacrymal glands are supplied only by the parasympathetic nerves. The functions of various cranial nerves have already been discussed earlier and *only* III, VII, IX and X *cranial nerves are parasympathetic.*

4

EXCRETION OF METABOLITES

(Structure of Kidney. Nephron—its different parts and their functions. Normal and abnormal composition of urine. Excretion through lungs and skin.)

Kidney, skin, lungs and gastrointestinal trach are the main channels through which excretion takes place.

Among the main channels of excretion, the kindneys are the chief organs where toxic products form urine and thus cause elimination of it from the body. This is the most important mechanism for maintaining the homeostasis of the body. These whole excretory organisms are composed of two kindneys, two ureters, one bladder and one urethra.

Urine is formed by the kindney from the blood. Ureter is the duct for transport of urine from kidneys to the bladder. Bladder is the reservoir of urine. Urethra is the passage through which urine passes from the bladder to the external environment.

Kidneys are two in numbers. These are bean shaped and are situated in the abdomen near the thoracolumber segments.

STRUCTURE OF KIDNEY

Longitudinal section of the kidney shows an outer region called cortex which appears as a dark reddish brown in colour. Inner

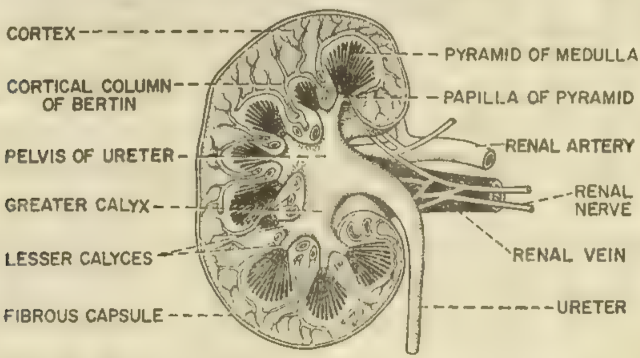


Fig. 21. Section of kidney is shown diagrammatically.

region is known as medulla. The medulla is divided into a number of conical areas called renal pyramids. The broad base of these

conical areas are situated in the cortex while the apex or papilla are projected into the lumen of the minor calyx (fig. 21). The kidney is made up of numerous functional units called nephrons. Each kidney possesses about one million of nephrons.

Structure of nephron

Each nephron has two parts: (1) Bowman's capsule, (2) Renal tubule. Bowman's capsule is the dilated blind end of the nephron which is surrounded by a tuft of the capillary vessels known as glomerulus. Thus Bowman's capsule and glomerulus constitute together a Mulpighian corpuscle or renal capsule. Mulpighian corpuscles are found only in the cortex of the kidneys. The structure of the nephron is shown in fig. 22.

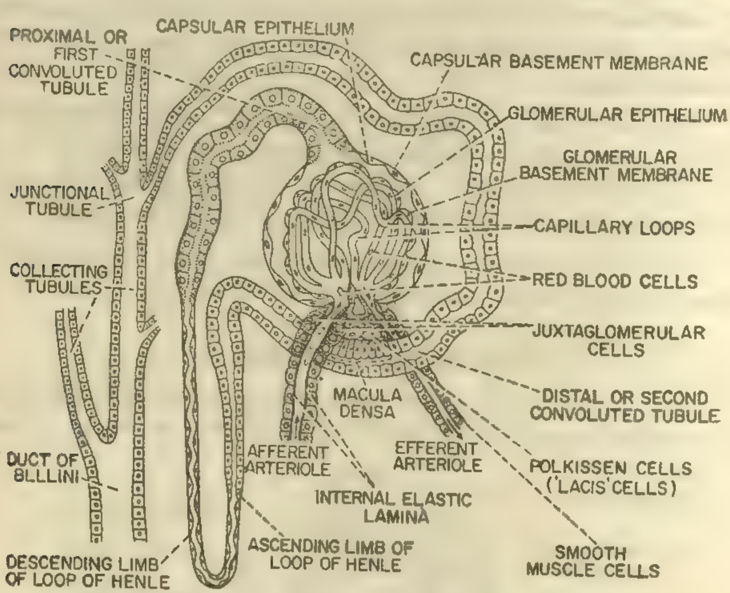


Fig. 22. Juxtaglomerular apparatus with the different parts of a nephron represented schematically.

Glomerulus—It is the capillary tuft. The afferent arteriole breaks up into numerous (about 50) capillary loops to form the glomerular tuft. The capillary tuft reunites to form efferent arteriole.

Bowman's capsule—It is the dilated blind end of the nephron. These are invaginated by the glomerular tuft.

The mulpighian corpuscle acts as a filtering organ. The filtering membrane of the mulpighian corpuscle contains three layers :

(1) endothelial cell layer of the capillary, (2) the basement membrane and (3) the epithelial cells of Bowman's capsule.

The glomerulus have two parts : (1) the vascular and (2) tubular. The human tubule is about 3 cm in length. Just below the glomerulus, the tubule (renal tubule) has a very short constricted portion called neck.

Renal tubules—The renal tubules consist of the following successive parts, (1) proximal convoluted tubule, (2) thin segment loop of Henle, (3) distal convoluted tubule, (4) collecting or straight tubule.

(1) *Proximal or first convoluted tubule*—It is about 14 mm long. It is lined by a single layer of cubical cells, the free borders inside the lumen are brush bordered. Brush border is composed of many microvilli which enormously increase the surface area for

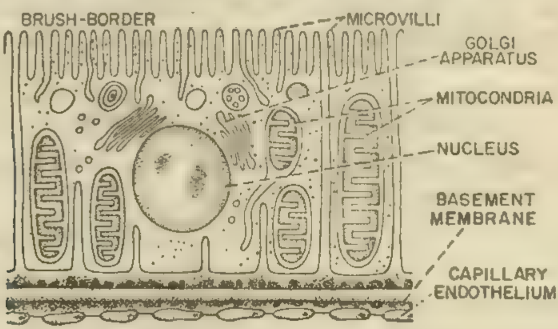


Fig. 23. Electron microscopic structure of the cell lining the first convoluted tubule.

absorption in the lumen of the proximal tubule (fig. 23). There are numerous tubular invaginations found at the clefts between the microvilli and these are extending downwards into the apical cytoplasm called apical canaliculi. These are involved in the cellular mechanism of absorption of protein from the filtrate. The cells of proximal convoluted tubule are very active metabolically and contain a large number of enzymes.

(2) *Henle's loop*—It is U shaped loop and contains a descending limb and an ascending limb. The major part of the descending limb is lined by epithelial cells with small microvilli. The distal part of the descending limb and some parts of the ascending limb are lined by flat epithelial cells.

(3) *Distal or second convoluted tubule*—This portion of the tubule is situated in the cortex and the length is about 5 mm.

It is lined by cubical epithelium which is rodded but without any true brush border. Microvilli are small in number. The diameter of the lumen of distal convoluted tubule is greater than that of proximal one. The proximal part of the distal convoluted tubule actually comes in contact with the juxtaglomerular cells of the afferent vessel. Juxtaglomerular complex includes: (a) granular juxtaglomerular cells in the afferent arteriole, (b) macula densa of the distal convoluted tubule and (c) agranular 'Lacis' cells situated in the angle created by the entrance and exit of the afferent and efferent arterioles of each glomerulus. The juxtaglomerular complex helps in control of blood pressure, renal blood flow, salt balance and erythropoesis. These cells also secrete renin.

(4) *Collecting or straight tubule*—It is lined by pale cuboidal cells. Many collecting tubules from different nephrons join successively and form an wider tubule called duct of Bellini. Duct of Bellini opens at the apex of the renal pyramid.

FUNCTIONS OF NEPHRONS

The main function of the nephron is to filter blood to form urine as a toxic product of the body.

The glomeruli act ultrafilters. The process of filtration in the glomerulus is a passive process. It filters all the constituents of plasma excepting the colloids (protein, fat etc). Thus capsular fluid must have the same composition as the plasma excepting its colloids. Filtering sizes of the pores are about 250-1000 Å. The size of the filtering pore is such that it allows only the molecules having less than 70,000 mol. wt. to pass. Serum albumin thus lies on the border line. Normally a very small amount of serum protein is present in the glomerular fluid and it is reabsorbed in the tubules. Albuminuria (i.e. presence of albumin in urine) is caused by the enlargement of the filtering pores in certain disease. 700 ml of plasma usually passes through the kidneys per minute. Out of this only 120 ml of filtrate is formed by the glomeruli per minute. It is known that about 170 litres of filtrate are formed by the glomeruli in 24 hours, where as only 1.5 litres of urine are usually excreted per day. Thus tubule may function as a great role in absorption of large amount of filtrate. The function of renal tubules are as follows :—

(1) *Selective reabsorption*—The renal tubules reabsorb water and other dissolved substances from the lumen of the tubule

and thus back it into the blood stream. The reabsorption may be selective and differentiable.

(2) *Tubular secretion*—Tubules can also actively transfer certain substances from the blood stream into the lumen of the tubules by active secretion.

(3) *Formation of some new substances*—Ammonia and inorganic phosphate are usually formed by tubular epithelium.

Protein and glucose are usually selectively reabsorbed by the proximal tubules. The reabsorption of water takes place in the proximal, distal and collecting tubules. ADH (antidiuretic hormone) controls the reabsorption of water in the tubule. The lack of ADH causes diabetes insipidus which is associated with the excretion of large quantity of water in the urine. Sodium is absorbed along with chloride. Reabsorption of Na^+ is an active process. It is reabsorbed mostly in the proximal tubule and slightly in the distal tubule. Potassium is reabsorbed in the proximal tubule. The secretion of potassium takes place in the second convoluted tubule. About 75% of urinary potassium is due to the process of secretion. Bicarbonate is completely reabsorbed in the renal tubules and pH of the urine is alkaline in reaction. Reabsorption of phosphate takes place in the proximal tubule. Tubular secretion is an active process.

The cells of the renal tubule contain deaminases which can produce ammonia by the deamination of amino acids and thus forms new substances in urine.

GENERAL FUNCTION OF KIDNEY

The general functions of kidney or nephrons are as follows :—

(1) It helps in excretion of waste and toxic products. The N_2 and sulphur containing end products of protein metabolism are excreted through the urines.

(2) It maintains pH and electrolyte balance of the body fluid.

(3) It maintains water balance of the body.

(4) It manufactures ammonia and inorganic phosphates and thus helps in metabolism.

(5) It maintains osmotic pressure in blood and tissues.

(6) It regulates blood pressure through the secretion of renin under certain condition.

NORMAL AND ABNORMAL COMPOSITION OF URINE

Nomal constituents of urine may be divided into (1) Organic and (2) Inorganic parts in the following way :—

Urine constituents

Organic		*Inorganic*	
1. Total Nitrogen	25-35 gm	1. Chloride	6-9 gm
2. Urea	24-30 gm	2. NaCl	10-15 gm
3. Creatine	60-150 mg	3. Phosphate	0.8-1.3 gm
4. Creatinine	1.4 gm	4. Sulphate	0.8-1.4 gm
5. Ammonia	0.7 gm	5. K	2.5-3.0 gm
6. Uric acid	0.7 gm	6. Na	4-5 gm
7. Oxalic acid	10-30 mg	7. Ca	0.1-0.3 gm
8. Amino acids	150-200 mg	8. Mg	0.1-0.2 gm
9. Vitamins, hormones and enzyme—small quantity.		9. I	50-250 μg

Normal urine is about 600 ml to 2500 ml per day. Some of the important constituents of urine are discussed in the following way :—

1. **Urea**—It constitutes about half of the total urinary solid. It is the principal end product of protein metabolism. It represents about 80-90% of the total urinary nitrogen. In nephritis, excretion of urea may be decreased.

2. **Ammonia**—It is also most important nitrogenous constituent. In nephritis ammonia excretion decreases.

3. **Uric acid**—It is the end product of purine metabolism. Excretion of uric acid increases in gout, leukaemia and severe liver disease. It is derived from the nucleoprotein of diet or may be from break down of cellular nucleoprotein.

4. **Creatine and creatinine**—In female, these constituents are higher than male. In starvation, excretion of creatine is increased.

5. **Oxalate**—Excretion of oxalic acid is increased in diabetes. It is the end products of glycine.

6. **Amino acids**—In liver diseases the excretion of amino acid is increased greatly.

7. **Vitamin, hormones and enzymes**—These are excreted in small quantity in the urine.

8. **Chloride**—Next to urea, it is the chief solid constituent of urine. It is mainly excreted as sodium chloride. In nephritis, diarrhoea, the chloride excretion is greatly reduced.

9. **Phosphate**—Urinary phosphate, comes largely from the end products of phospholipids, phosphoprotein of the diet and tissues. Phosphaturia is a condition when urine contains a crystalline precipitate of magnesium or ammonium phosphate. Kidney or bladder stones are the result of precipitation of the insoluble inorganic phosphates. In certain bone diseases, the excretion of phosphate increases.

10. **Sulphates**—Urinary sulphates are usually derived from the metabolism of sulphur containing amino acids.

11. **Minerals**—Na^+, K^+, Ca^{+} and Mg^{++} are usually present in the urine. In Addison's disease i.e., hypofunction in adrenal cortex may cause an increase of sodium and a decrease of potassium excretion in urine. Potassium and sodium ratio is normally about 3 : 5.

ABNORMAL CONSTITUENTS OF URINE

Abnormal constituents of urine are listed in the following way. These are usually formed due to malfunction of kidney or due to defects in some other parts of the body.

1. **Protein** (mainly albumin and globulin). Proteinuria is the condition where albumin and globulin are present in large amount in the urine. Nephritis and nephrosis cause a large excretion of urinary protein as albumin and globulin.

2. **Glucose**—Abnormal excretion of glucose in the urine is called glycosuria. In diabetes mellitus, glucose is excreted more than 140 mgm per 24 hours through the urine.

3. **Other sugars**—Other sugars such as fructose, galactose, lactose and pentose may be excreted in various diseases.

4. **Ketone bodies**—In diabetes, starvation, pregnancy, the excess ketone bodies are excreted in the urine.

5. **Blood**—Acute inflammation of the kidney may cause excretion of blood in the urine. Tuberculosis, cancer patient may cause an excretion of blood in the urine.

6. **Pigments**—A number of pigments, bilirubin, melanin, urochromogen may excrete through the urine in abnormal condition e.g. tuberculosis. Bilirubin is excreted through the urine in obstructive jaundice.

7. Pus—Pus cells are often found as abnormal constituents of urine.

8. Hormones—In different physiological and pathological conditions, the adrenal steroids and gonadal hormones are excreted through the urine. In adrenocortical carcinoma, hyperplasia of the cortex and testicular tumors, the 17 ketosteroids are excreted in large amount in the urine.

EXCRETION THROUGH LUNGS AND SKIN

Though kidney is the main excretory organs, the excretions through lungs and skin are also very important.

1. Lung mechanism

The end products of the metabolism in the tissues are CO_2 and H_2O. The accumulation of CO_2 in the tissue would be toxic to the body until it is excreted from the tissues. The venous blood carries this CO_2 to the lungs through pulmonary circulation to excrete it from the body by expiration. CO_2 is carried out by the blood in three forms. These are: (1) physical solution in the blood, (2) carbamino compound and (3) bicarbonates. Major portion of CO_2 is carried out as bicarbonates. About 4 ml of CO_2 per 100 ml of venous blood is excreted and thus 100 ml arterial blood contains 4 ml CO_2 less than that of venous blood. If the cardiac output is 5 litres per min about 200 ml of CO_2 (i.e. $\frac{4}{100} \times 5000$) would be excreted through the lungs to the external environment per minute. Carbonic anhydrase found in the RBC of blood helps to form bicarbonate while the same enzyme in the lungs by its reversible reaction forms CO_2 and H_2O. The CO_2 is thus escaped to the environment from the lungs. Besides the excretion of CO_2, some vapours are also escaped from the lungs to the external environment.

During exercise more CO_2 and more vapour are usually escaped from the lungs by increasing respiratory rate and depth i.e., by increase of ventilation.

2. Skin mechanism

The skin is also acting as an excretory function of the body. Due to the presence of sweat gland, the skin helps in excretion of certain substances by the sweat secretion (sweat is the active secretion of the sweat glands).

Structure of the sweat gland—Usually sweat glands are coiled and unbranched tubular glands. The secretory portion of the gland is deeply embedded in the dermis or even in the subdermis layers of the skin as a coiled mass. These are shown in fig. 24. The excretory duct passes through the epidermis in a spiral course and opens to the surface through an opening, the sweat pore. The

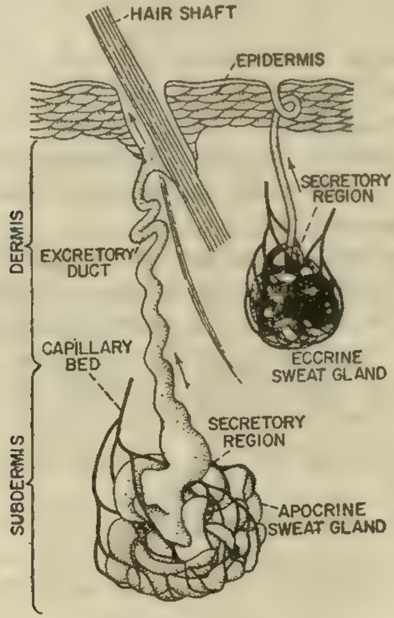


Fig. 24. Schematic representation of the structure of sweat gland.

secretory portion of the gland is lined with a single layer of cuboidal to columnar cells. There are about 2 to 3.5 millions of active sweat gland. These are of two types : (1) Eccrine and (2) Apocrine.

(1) *The eccrine glands* are distributed throughout the whole surface of the body. These are abundant on the palms and soles. These are innervated by cholinergic but sympathetic fibres whose discharge is dependent on the deep body temperature.

(2) *The apocrine glands* are larger sweat glands. These sweat glands are found only in special region, such as axilla, mons pubis, labia majora etc. These glands become active with the onset of puberty. The secretion of these sweat glands has a characteristic odour.

The sweat is not a simple filtrate of blood. Secretion of sweat is an active process.

The total amount of sweat secreted daily is about 500 ml. During exercise the sweat secretion becomes abundant.

Function of sweat gland—The function of the sweat gland is mainly the excretion of various metabolites which are toxic to the body. The secretion of sweat helps in many ways to maintain homeostasis of the body. These are: (1) it maintains or controls the heat regulation mechanism of the body, (2) it helps in water and salt balance, (3) it maintains acid base balance in the tissues, (4) it excretes large amount of toxic products as the end products of various metabolites. It excretes NaCl, urea, lactate, creatine, uric acid, ammonia, amino acids, glucose, water soluble vitamins (B & C), sodium, potassium, calcium etc.

The rise of external temperature stimulates sweating (visible). Rise of body temperature as in exercise also stimulates the sweat secretion. In the body, sweat is secreted every day and it is about 500 ml/day. The insensible perspiration occurs every moment i.e., the loss of water from the skin is neither visible nor perceptible. The insensible perspiration is not due to any active secretion but is due to passage of water by diffusion of tissue fluid through the epidermis.

Emotional sweating occurs chiefly in the palms, soles and axilla. Emotional sweating is caused by the discharge of impulses from the higher centres which effect directly the sweat glands.

5

REPRODUCTIVE PHYSIOLOGY

(Structure of gonads and their function. Gametogenesis and Fertilization. Control of fertility and population.)

Gonads are the primary sex organs. The male gonad or the generative organ is called testis. The female gonad is known as ovary.

Testis and ovary possess two functional components. One component secretes hormones while the other produces gametes. The production of gamete is controlled by these hormones.

The onset of reproductive life is called puberty i.e., it is the time when gonad develops both endocrine and gametogenic functions. Puberty usually starts between 12 to 16 years. In female it occurs about 2 years earlier than male.

The male generative organs consist of testes, epididymis, vas deferens, seminal vesicles, ejaculatory duct, prostate, cowper's glands and penis.

The female reproductive organs are the following: ovaries, Fallopian tubues, uterus, Bartholin's glands & vagina.

Except testes and ovaries all these organs are known as secondary or accessory sex organs. In female, breast is also an accessory sex organ.

The secondary sex characters begin in male by a change of voice with appearance of beard and moustache. In females, breasts develop and most characteristic feature is the onset of menstruation cycle. Mental change is associated with the desire of sex. In this stage gonads develop and produce mature gametes.

STRUCTURE AND FUNCTION OF MALE REPRODUCTIVE ORGANS

The testes remain inside the scrotum. These are two in number and the shape is in the form of oval body.

The testis is covered by a tough, compact, fibrous capsule called tunica albuginea. It is divided into a number of pyramidal lobules. The lobules are filled up with convoluted tubules known as seminiferous tubules. Several tubules unite to form straight tubule. The straight tubules unite to form rate testis (fig. 25). These join up to form vasa efferentia. All the vasa efferentia combine to form

the duct of epididymis. Epididymis continues as vas deferens. The vas deferens opens to the seminal vesicles which is a musculo-glandular sac and opens into the prostatic urethra. The secretion of the prostate and seminal vesicles constitutes a major part of the semen. Urethra continues as a passage of semen to the outside

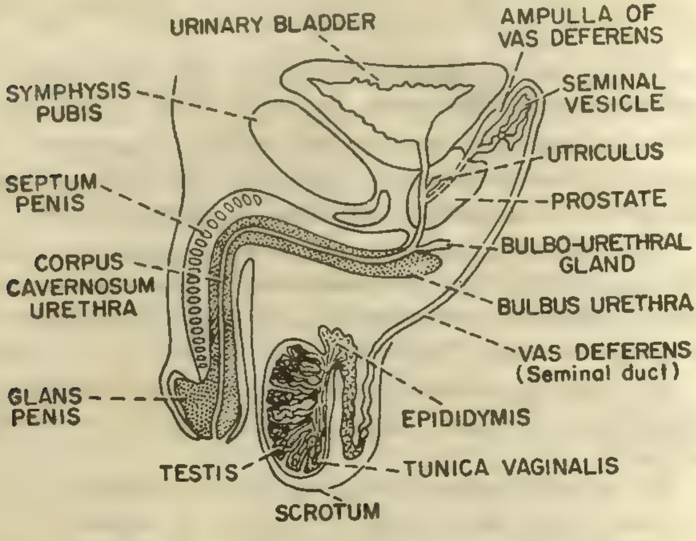


Fig. 25. Male reproductive organs.

by the ejaculatory organ, penis. The epididymis acts as a store house of spermatozoa until ejaculation occurs. Spermatozoa are the units of male gonad.

Structure of testis—The outer fibrous covering of the testis is known as tunica albuginea, from which trabeculae descend. It is then divided into many lobules. Each testicular lobule contains one to three convoluted sperm producing tubules called seminiferous tubules. These are lined with 4 to 8 layers of cells, each layer represents a particular stage in the development of spermatozoa. Spermatogenesis (i.e. gametogenesis) takes place in the seminiferous tubules (fig. 26). Interstitital cells (i.e., cells of Leydig) are usually found between the various seminiferous tubules and these are groups of polyhedral cells. These cells represent the endocrine tissue of the testis which secrete testosterone.

Function of testis—The function of testis may be divided into two major parts. These are (1) Spermatogenesis and (2) Secretion of testosterone hormone (androgen).

The seminiferous tubules perform the function of spermatogenesis. The section of testis shows the various process of spermatogenesis within the seminiferous tubule (fig. 27). It may

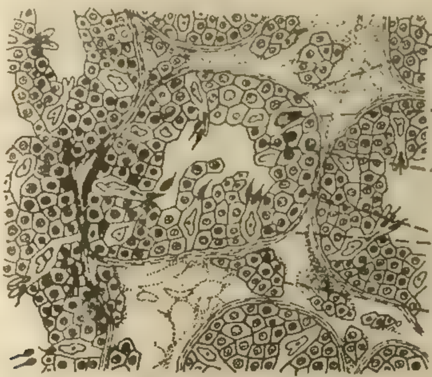


Fig. 26. Section of normal human testis.

be shown that spermatogonial cells are lined inside the basement membrane which in successive layers show their maturation to spermatozoa.

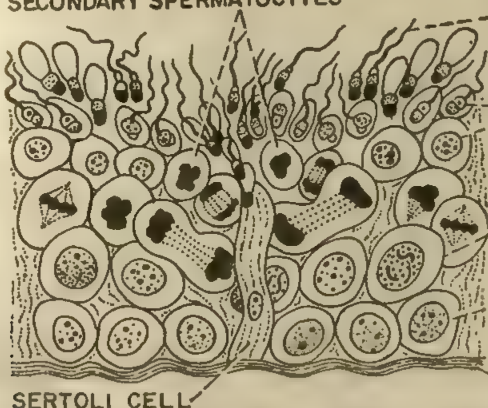


Fig. 27. Diagrammatic representation of arrangement of cells in the seminiferous tubule. This shows various progression of spermatogenesis.

The Leydig cells secrete testosterone which have multiple functions. The major function is to cause the growth of various accessory male sex organs including the seminal vesicles. The testosterone is essential for the development of male secondary sex characters.

SPERMATOGENESIS

The major functions of the testis are to produce spermatozoa. The stages of development of spermatozoa are known as spermatogenesis. In male this process begins during adolescence under the influence of pituitary gonadotrophin hormones. This process is also known as gametogenesis.

The germ cells are known as spermatogonia. These are situated in the peripheral portion of the seminiferous tubules of the testes.

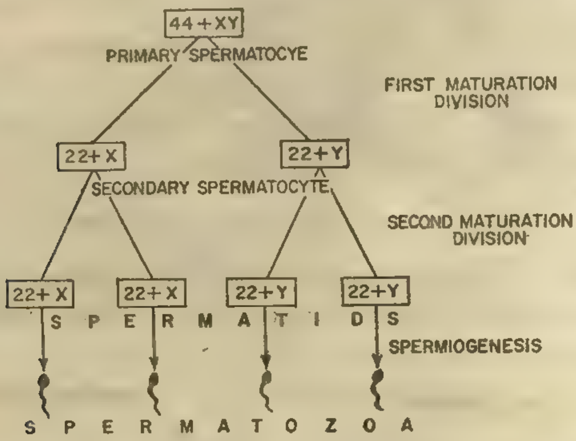


Fig. 28. Maturation division of male germ cells. XY chromosomes divided into 2 X and 2 Y, i.e., 4 spermatozoa are produced.

The Spermatogonial cells divide and increase in number and gradually move towards the centre of the seminiferous tubules. These cells are known as primary spermatocytes.

Primary spermatocyte undergoes meotic (reduction) division and produces two secondary spermatocytes. Each secondary spermatocyte divides again to form two spermatids.

The secondary spermatocyte contains 23 double chromosomes while each spermatid receives only 23 single chromosome. After maturation each spermatid becomes spermatozoon. Thus four spermatozoa are produced from a primary spermatocyte. One half of spermatozoa carry X chromosome and another half carry Y chromosome. These are shown in fig. 28. The spermatozoa contribute sex chromosomes which determines the sex of fertilised ovum as each ovum normally contains one X chromosome. After fertilization the original complement of 46 chromosomes is established.

The morphologic transformation of spermatids into spermatozoa is known as spermiogenesis.

The Spermatozoon usually consists of head, neck, body and tail. (fig. 29).

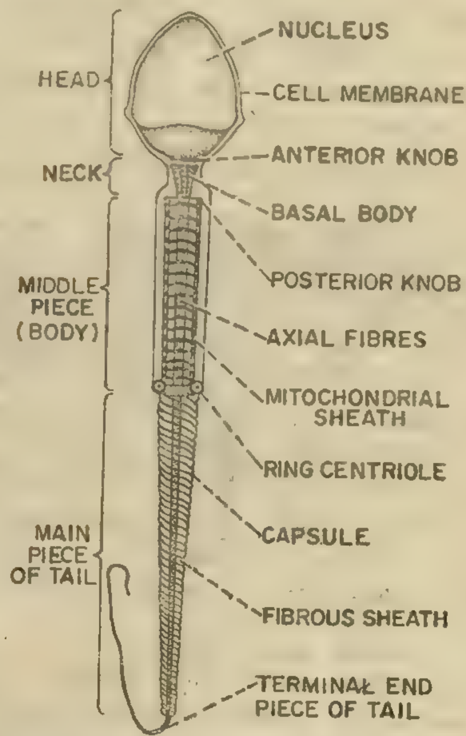


Fig. 29. Diagrammatic representation of a spermatozoon.

Head—The head is the nucleus. It is flat and oval. Size is about 4-5 μ.

Neck--The neck is short and it connects head and body.

Body (middle piece)—The body contains a ring of fibrils. It is also surrounded by spiral mitochondrial sheath.

Tail—It is composed of two parts:

(a) main piece and (b) terminal end piece.

The main piece of tail consists of a spiral mitochondrial sheath surrounding a group of fibrils. It helps in movement of the spermatozoa.

The terminal end piece of tail consists of the extreme portion of the fibrils and has no covering sheath. This structure has the characteristic of cilia.

The total length of the spermatozoon is about 60 μ. About 100,000 spermatozoa may be found in one cubic mm of semen. (Semen is the discharge of male generative organs).

STRUCTURE AND FUNCTION OF FEMALE REPRODUCTIVE ORGANS

The female reproductive organs consist of the following parts and these are shown in fig. 30. :—

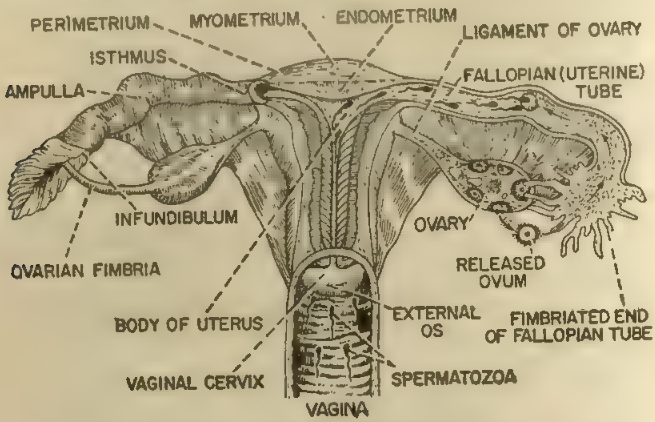


Fig. 30. Various parts of the female reproductive organs.

(1) *Two ovaries*, one on each side.

(2) *Two connecting Fallopian tubes* in the pelvis. These tubes terminate near the ovaries in one end while the other end connects the uterus. Each tube near the ovary enlarges and forms ampulla and infundibulum and these end in a fimbriated margin of which one is attached to the ovary and is called ovarian fimbria.

(3) *Uterus* is a thick walled and pear-shaped muscular organ. The inside of the uterus is hollow. The upper part is called body while the lower part is known an cervix which is continuous with the vagina below by the *external os*. The inner mucous layer of the uterus is called endometrium and is lined by epithelial cells. The endometrium undergoes cyclic changes during different phases of *menstrual cycle*. The main function of the uterus is to maintain the growth and development of the embryo.

(4) *The vagina* is a musculomembranous tube and it is situated below the cervix and it extends downward to the exterior genital opening. This is the passage through which sperm first finds its way to fertilize the ovum in the endometrium of the uterus. The

ovum (female gamet) discharged by the ovary is transported to the uterus along the Fallopian tube. If the ovum is not fertilized without the act of conjugation the uterus weeps for the discharged ovum and the funeral of the unfertilised ovum is observed by the menstruation. The cyclical discharge of blood from the uterus in the reproductive life of the females, with an interval of 28 days is called *menstruation.*

During each cycle of menstruation, the uterine mucosa proliferates and prepares a suitable bed for the reception and implantation of the fertilized ovum. If fertilization takes place (i.e. pregnancy) this proliferated mucosa is converted to a placenta for nourishment of baby. If it is not fertilised, the hypertrophied mucosa breaks down and is discharged as menstruation. The details would be discussed in the latter part. The structure and function of the ovary are now discussed below.

STRUCTURE AND FUNCTION OF OVARY AND GAMETOGENESIS (OOGENESIS)

STRUCTURE OF THE OVARY—The ovary is developed fully only at the puberty. The histological structure of ovary consists of the following parts and it is shown in fig. 31.

(1) *Germinal epithelium*—The outermost covering of the ovary is lined with a single layer of cuboidal cells and is known as germinal epithelium.

(2) *Tunica albuginea*—It is a thin layer of collagenous connective tissue and is situated under the germinal epithelium.

(3) *Stroma*—It is also a connective tissue network and is continuous with the tunica albuginea. It is a supporting structure of the ovary.

(4) *Graafian follicles* (Vesicular follicles)—These are the most important constituents of ovarian cells. These are distributed as many small islands of cells with various stages of development and are scattered mostly at the peripheral part of the ovary. The immature one is called the primordial follicle. The central cell is the ovum. It is spherical in shape. The mature Graafian follicle is shown in fig. 32. It consists of the following parts.

(a) *Theca externa* (tunica fibrosa) is the outer fibrous layer.

(b) *Theca interna* (tunica vasculosa) is the inner vascular layer.

(c) *Membrana granulosa* are multilayered cells and are distributed peripherally.

(d) *Discus proligerus* are the innermost cumulus cells and surround the ovum in radial fashion.

(e) *Liquor folliculi* is the fluid found in the cavity of the Graafian follicle which on maturation causes an increase of pressure and thus follicle ruptures. The ovum surrounded by the discus cells, is discharged into the peritoneal cavity near the open end of the Fallopian tube. The process of rupture of the Graafian follicle is called *ovulation*. Ovulation usually occurs after 14 days from first day of last menstruation.

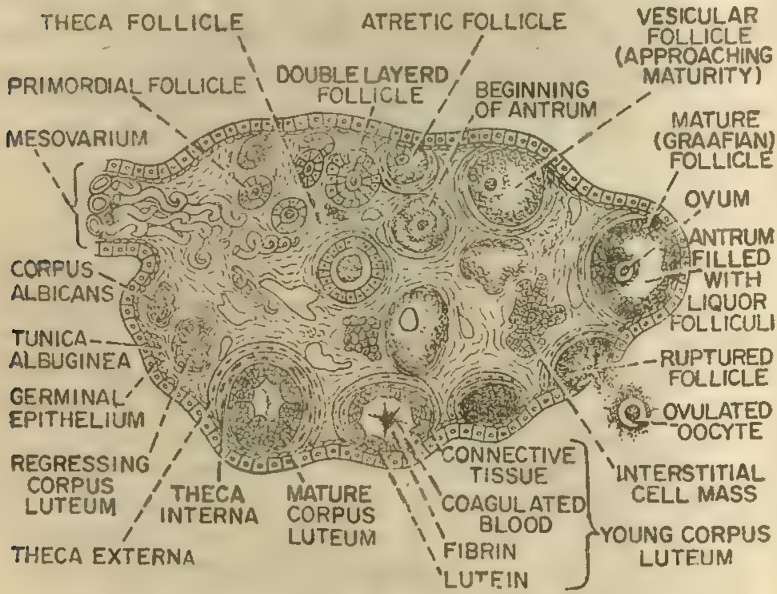


Fig. 31. Structure of ovary is shown with the development of follicle and corpus luteum.

(5) *Corpus luteum*—Corpus luteum grows on the ruptured follicle after ovulation. The granulosa and stroma cells rapidly multiply and fill up the cavity and thus corpus luteum is formed. It attains its maximum size in the 19th day of menstruation cycle. In absence of pregnancy, it persists upto 27th day and degenerates on the 28th day, when menstruation begins. The cells of the corpus luteum consist of column of large conical cells with distinct nucleus and granules which cause secretion of hormones as a temporary gland. The corpus luteum is essential for the maintenance of pregnancy and its size becomes maximum at 3 to 4 months of

pregnancy. It degenerates at the latter months forming a fibrous scar.

(6) *Interstitial cells*.—These are groups of polyhedral cells and contain granules. They develop from the stroma cells or from

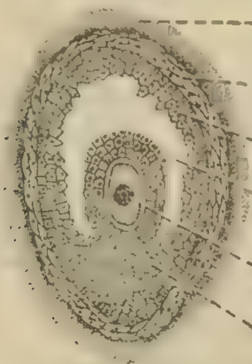


Fig. 32. Structure of the Graafian follicle.

the cells of the unruptured follicle. These cells probably secrete the hormone oestrogen.

FUNCTION OF THE OVARY

The function of the ovary is to control the whole reproductive life of the female. It has got both exocrine and endocrine functions.

The exocrine function is the formation of mature ova i.e. gametogenesis or maturation of the ovum.

The endocrine function is performed by secretion of various hormones such as oestrogen, progesterone, androgen and relaxin. It performs the following functions :

(1) It causes the necessary changes associated with puberty such as (a) appearance of secondary sexual characters, (b) growth and development of the uterus, Fallopian tube, vagina, (c) menstrual changes.

(2) During pregnancy it helps : (a) in embedding of ovum and (b) in development of placenta.

(3) Due to release of the hormone relaxin, it helps in parturition (i.e., child birth).

(4) Oestrogen helps in development of mammary gland by proliferation of ducts. Progesterone stimulates mainly lobuloalveolar growth of the mammary gland.

The only main functions of the ovary are discussed below in detail, such as:

(1) *gametogenesis*, (2) *Ovulation*, and (3) *Menstruation*.

(1) GAMETOGENESIS

Before ovulation, the ovum undergoes the process of maturation within the Graafian follicle. The primary oocyte of the Graafian follicle undergoes first meiotic (reduction) division and gives rise to one secondary oocyte and one polar body. This

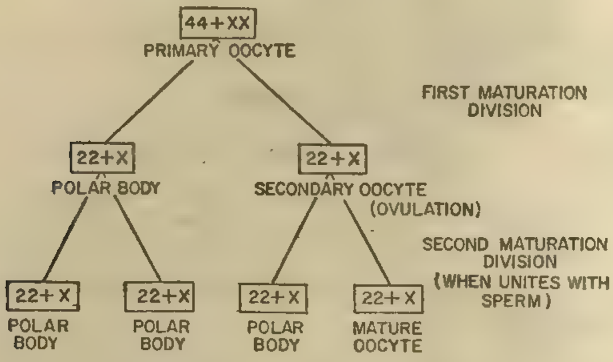


Fig. 33. Maturation divisions of female germ cell having 2 X chromosomes. This results one X chromosome as mature oocyte.

division is of heterotypical and is shown in fig. 33. Graafian follicle ruptures and causes ovulation by discharging the ovum as a secondary oocyte. This secondary oocyte contains half the number of standard chromosome as 22+X. Further differentiation of the secondary oocyte occurs only when sperm fertilises the ovum in the Fallopian tube i.e., second meiotic division takes place only when sperm penetrates the zona pellucida of the secondary oocyte and thus matured ovum (22+X) is formed by loosing another polar body. This division of the secondary oocyte is homotypical.

(2) OVULATION

The process of rupture of the Graafian follicle is known as ovulation. Ovulation usually occurs between 13th to 17th (average 14th) days after the commencement of menstruation. Ovulation widely varies from one individual to another. There is also no certainty that the day of ovulation will remain constant for the same individual from cycle to cycle. Only one follicle matures and

only one ovum is discharged at each menstrual cycle. The exact span of life of the ovum is not known. But it does not remain functionally active after a few days.

The corpus luteum is formed immediately after the ovulation. The formation and function of corpus luteum have already been discussed earlier.

(3) MENSTRUATION

The menstruation is the cyclical discharge of blood, mucus and other substances from the uterus through the vaginal opening and it occurs at an average interval of 28 days. It persists for a period of 4-6 days and causes no appreciable pain.

Menstruation starts at puberty and ends at menopause. Menopause is the cessation of menstruation and it terminates the reproductive life of the female usually at an age of 45 to 55 years.

First commencement of menstruation in female is usually observed between 12 to 16 years of age.

The composition of menstrual fluid are the followings:

(1) Blood (about 30-40 ml and partially clotted)

(2) Stripped of endometrium

(3) Mucus

(4) Leucocytes

(5) Unfertilised ovum.

During each cycle the endometrium of uterus gradually hypertrophies. Its purpose is to prepare a suitable bed for the reception and implantation of the fertilised ovum. If pregnancy does not occur, the hypertrophied mucosa of the endometrium breaks down and is discharged as menstruation and escapes through the vaginal opening to the outside of the booy. Thus menstruation may be described as a funeral of the lost and unfertilised ovum.

The endometrial changes during the whole period of menstrual cycle (i.e., 28 days) have been divided into 4 stages.

These are:

(1) Resting or postmenstrual phase,

(2) Proliferative or oestrogenic phase,

(3) Luteal or premenstrual phase, and

(4) Menstrual phase.

The 1st and 2nd stages are called follicular phases and persist for a period of 2 weeks. The last 2 weeks are known as luteal phase.

The gonadotrophin hormones of anterior pituitary gland control the phases of menstruation cycle. These are FSH (follicle stimulating hormone), LH (Luteinising hormone) and LTH (Luteotrophic hormone). These hormones act both on Graafian follicles (by FSH) and corpus luteum (by LH & LTH) so that oestrogen and progesterone are secreted and these may cause a various functional changes in the endometrium and ovary. These are shown schematically in the fig. 34.

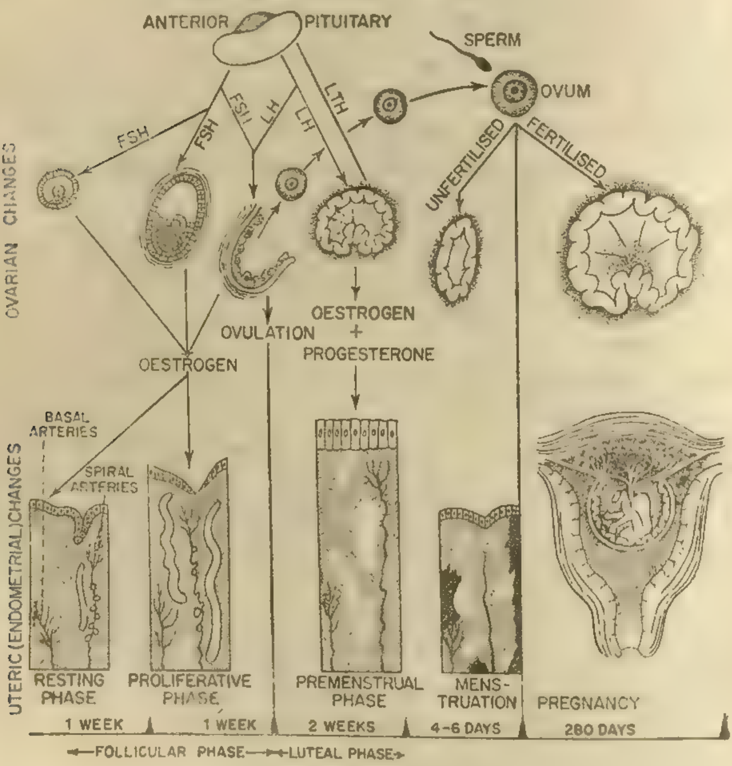


Fig. 34. Diagrammatic representation of uteric and ovarian changes in menstrual cycle with the control mechanism of hormones.

The phases of uterine and ovarian changes with cause and control of menstrual cycle (28 days) have been discussed in the following way :—

Phases and the changes in endometrium (Uterus)	Ovarian changes	Hormonal changes	Cause and control
1. *Resting phase.* Duration is about 1 week. Endometrium heals up and shows a slight proliferative changes.	Follicle slowly matures.	Oestrogen secretion rises from the maturing follicle.	Beginning of the proliferative changes of endometrium is controlled by the secretion of oestrogen from the follicle through FSH.
2. *Proliferative phase.* Duration is 1 week (6-14th day). Mucosa of the endometrium becomes more vascularised and thickened with dilatation of glands and blood vessels.	Graafian folicle matures fully and ruptures on the 14th day. Corpus luteum formation starts as ovulation occurs.	Oestrogen secretion rises maximally at the end of 2 weeks. It stimulates LH to form corpus luteum.	These uterine changes are caused further by the high level of estrogen controlled by FSH.
3. *Premenstrual phase.* Duration is about 2 weeks. (15th to 28th day). Mucosa thickends much. Glands distend much. Capillaries dilate as sinus. Stroma cells proliferate.	Corpus Luteum grows and attains maximum size on the 19th day which continues upto 27th day. It is degenerated on the 28th day.	Progesterone secretion takes place in corpus luteum. Oestrogen secretion falls. Increased progesterone at the end of 2 weeks inhibits LH and LTH.	The uteric changes caused by the secretion of progesterone which is controlled by LH and LTH of anterior pituitary. At the end of 2 weeks progesterone secretion falls by inhibition of LH & LTH and thus menstruation commences.
4. *Menstrual phase.* Menstrual flow starts on 28th day and continues for 4-7 days. Endometrium breaks up with blood-stained fluid. Mucus and unfertilised ovum pass out in the dicharge.*	Corpus luteum degenerates. Placental gonadotrophin is necessary for its further growth. In absence of pregnancy corpus luteum degenerates as placenta is not formed.	Progesterone secretion 2 weeks are oestrogenic phase and the last 2 weeks are progesteronic phase.	Lack of progesterone is the cause of bleeding which also stimulates FSH and thus resumes menstrual cycle for maturation of the another follicle.

* During the menstrual phase discharge of blood is a continuous and a slow process. Thus the woman usually uses pads made up of cotton to absorb and soak the fluids and it is changed at frequent intervals by proper washing of the vaginal aperture.

FERTILISATION

Fertilisation takes place when sperm unites with ovum. After the sexual conjugation the semens containing sperms are ejaculated by the *erectile penis* inside the *vaginal canal.*

After the entry into the vagina, the spermatozoa travel to the Fallopian tube through the vaginal cervix and the body of the uterus. It takes about 45 minutes and travels usually at the rate of 1-3 mm per minute. If the ovum is present, fertilisation takes place by the penetration of the sperm to it. Only one sperm is allowed to penetrate the ovum and after penetration it causes barrier for other sperms. If the ovum is not present, the sperm usually dies and degenerates after 72 hours. Similarly it has been shown that ovum takes about 72 hours to arrive at the uterus after ovulation and it lives and remains functionally active for a few days only. The best change of fertilisation (or pregnancy) lies in the *third week* and least chance in the *first* and *last* week of menstrual cycle.

After fertilisation, the ovum multiplies at a terrific speed and thus forms morula which reaches to the body of the uterus from Fallopian tube within a period of eight days. Implantation on the uterus usually takes place shortly by embedding of the fertilised ovum and thus pregnancy starts and causes the formation of placenta. Normally it lasts for 280 days (approximately 9 months and 10 days) from the date of last commencement of menstrual cycle. (Thus stoppage of menstrual cycle after the conjugation is the first sign of pregnancy). Placenta helps in the nourishment of the baby within the womb of the mother. After full growth baby becomes self-sufficient in performance of various physiological functions and thus escapes out from the womb by rupturing the placenta. This is known as parturition which results in child-birth. During perturition, the birth canal (cervix and vaginal canal) is enlarged by various hormones such as relaxin (secreted by the ovary and placenta). Oxytocin secreted from the posterior pituitary also causes vigorous contraction of the uterus and thus helps in parturition.

CONTROL OF FERTILITY AND POPULATION

The world population is increasing day by day but the balance with increasing food production is a question and doubtful. The population is expected to be doubled by 2000 A.D. As the increase demand of food production is a great problem, the con-

trolled reproduction and a planned family have been given much attention recently. In India, this problem is maximum and it is ignored as most of the peoples are uneducated. In order to make a successful control on family planning the sex education with different means of contraceptive device should be compulsory to each of the people. A man may not produce the need of his food but can control his own fertility. It is true for both man and woman. Contraception and controlled fertility are the devices to resist in any way either sperm or ovum to unite and thus it checks up fertilisation or conception. In beginning it should be kept in mind that the sexual conjugation (intercourse) is a most pleasurable enjoyment for both husband and wife. Thus a little sacrifice from both the ends is necessary to control family planning. The various techniques of family planning are discussed below :—

1. Barriers to the entry of sperm

The principle of this method is to produce a barrier so that sperm can not enter into the vaginal cervix. These are the following ways :—

(a) *Use of condoms*, a thin rubber sheath over the penis (i.e., Nirodh).

(b) Use of thin rubber *diaphragm* on the cervix.

2. Spermicidal agents

The spermicidal agents may be used before or after the intercourse in the vaginal cervix which causes destruction of sperms such as various specific creams, pastes, jellis etc. These also help in better lubrication.

3. Vaginal Douches

Vagina may be washed out immediately after intercourse.

4. Interruption of normal path of the sperms or ovums

These may be applicable for both male and female.

(a) *Vasectomy* in male and (b) *Tubectomy* in female. Ligation of the vas deferens in male is called vasectomy. Ligation of the Fallopian tube is called tubectomy. Vasectomy, in males causes no ejaculation of sperms in the semen. Similarly tubectomy in female causes no discharge of ovum in the Fallopian tube. These are permanent device for family planning. It should be applicable for those peoples who have already more children.

5. *Loop device*

Loop is an intra-uterine contraceptive device (IUCD) and has been widely tried in India. If a foreign body is placed within the uterus, the implantation of fertilised ovum in the uterus is inhibited. In some cases this loop may cause excessive bleeding during the menstrual period and pain may also occur due to uterine cramp. Failure rate is less than about 5 per cent.

6. *Withdrawal technique*

The withdrawal of penis immediately before ejaculation of the semen is also a common technique. Failure rate of this technique is about 15 per cent.

7. *Rhythm method or safe period*

Women having regular menstrual cycles usually experienced the ovulation between 9 to 19th day after the beginning of the menstrual flow. Ovum remains alive for only few days while the spermatozoa entering the uterus remains alive about 72 hours. During this period intercourse should not be performed. But the exact day of ovulation in women is really uncertain and also varies from cycle to cycle. However the safe period in the case of women whose cycle starts from 25 to 32 days would be upto first 7 days (i.e., $25 - 18 = 7$) and from days of 21 onwards (i.e. $32 - 11 = 21$). Thus first and last week are approximately the safe period for the women. *It should be remembered that* 18 *is to be subtracted from the shortest recorded cycle and* 11 *is to be subtracted from the longest cycle.* Safe period is uncertain as the day of ovulation varies from cycle to cycle even.

8. *Oral contraceptives*

The use of hormones or combination of hormones which prevent conception is known as oral contraceptive pills. These are used by the female and are most effective. These are 100 per cent successful in preventing pregnancy if properly taken. Exact mode of action of various contraceptive pills are not known with certainty. However the classical pills usually inhibit the ovulation by various means e.g. suppressing LH output, modifying the transport of ovum, nidation of the fertilised ovum etc. Use of oral contraceptive pills may not cause any alteration of normal physiological function of the body. Long term use may cause hypertension in women. Oral contraceptive pills for male are under study and are not finalised.

9. *Abortion*

Abortion is a method of contraception when conception has already been taken place. The adaptation of this method is widely used to control the explosion of population in various western countries. It is now legalised even for the unmarried girls and this is perhaps the last resort for controlling the population.

The best method of contraception has not yet been accepted by any standarized technique. This may be suggested that alternate use of condom (Nirodh) by males and oral contraceptive pills by females are of advantageous techniques. Because use of oral contraceptive pills for a short peeriod of 2 or 3 cycles may not cause any appreciable side effects. Course of oral contraceptive pills should not be missed for any day. Missing is the only cause of conception.

Use of prostaglandin in contraception is of advantageous techniques for abortion and it is now widely used.

6

MUSCULO-SKELETAL SYSTEM-LOCOMOTION

The musculoskeletal system is a mechanical device of evolution in bioengineering aspects of vertebrates. This system not only helps in coordinated movements but also it gives support and protection of various internal organs. The development of musculoskeletal system in human is superior in these senses as it allows the man an erect posture to move on with the feet and skill works with the hands.

COMPOSITION OF MUSCULOSKELETON SYSTEM

The musculoskeletal system is composed of four parts. These are (1) bone, (2) skeletal muscle, (3) tendon and (4) ligament.

Bone is the connective tissue. The skeletal framework is composed of bones which renders shape and support of the body. Adjacent bones are attached to one another by joints in such a way that it provides the motion of the articulating bones.

Muscles responsible for the movement and positioning of the segments of the body are known as skeletal muscles. The skeletal muscles are striated and have the properties of extensibility, elasticity and contractility. This enables also the source of energy for specific movements.

Tendons are simple continuation of muscles connective tissue and possess the same properties as muscles. It is the connecting parts by which muscle joins with the bone and helps in movement of the joints.

Ligaments are the connecting parts of the two bones in the joint. This helps in coordination of movements to a specific direction only. Ligaments are strong, flexible, stress resistance and somewhat elastic and fibrous tissues. They attach the ends of the bones which forms a movable joint.

Mechanically speaking, the total bone joint muscle structure is an intricate combination of levers which makes possible to a coordinated movement. A lever is defined as a rigid bar which turns about a fulcrum (fixed axis or pivot) when a force is applied to it at some specific point. Force is applied by the contraction of the adjacent muscles. Joint movements are of various types and these would be discussed after describing the skeletal frame work and the various muscular system of the human body.

SKELETAL SYSTEM (BONES)

The bones are the constituents of skeletal system. The systems are of two major parts. These are (1) axial skeleton and (2) appendicular skeleton.

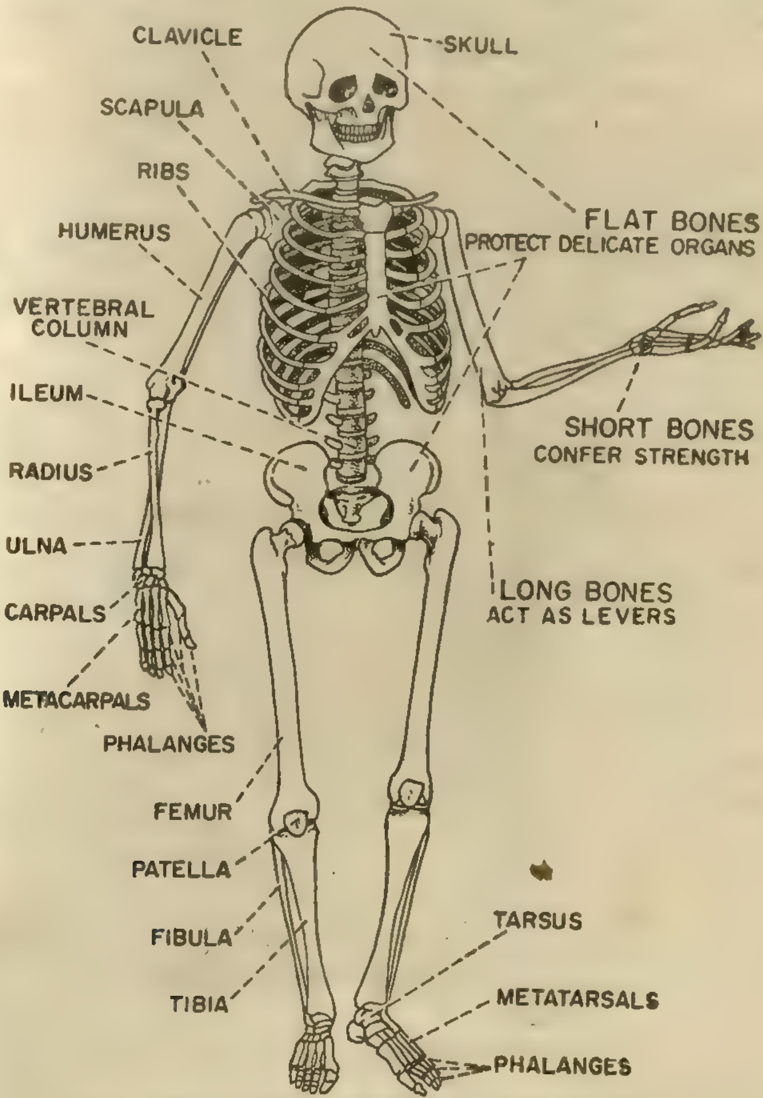


Fig. 35. Skeleton system of human body.

Axial skeleton—The axial skeletons consist of skull, spinal column, sternum and ribs.

Appendicular skeleton—It includes the bones of upper and lower extremities. The bones of the upper extremities include the scapula, clavicle, humerus, ulna, radius, carpals, metacarpals and phalanges. The lower extremity includes femur, tibia, fibula, tarsals, metatarsals and phalanges. Pelvis is described either an axial or an appendicular skeleton. These are shown in fig. 35.

The bones are classified into four major categories due to their great variety in size and shape. These are (1) long, (2) short, (3) flat and (4) irregular.

Long bones—The bones belonging to this category are the clavicle, humerus, ulna, radius, metacarpals, phalanges, femur, tibia, fibula, metatarsals. The long bone mainly acts as lever.

Short bones—The carpals and tarsals (wrist and ankle bones) belong to this category. It confers strength.

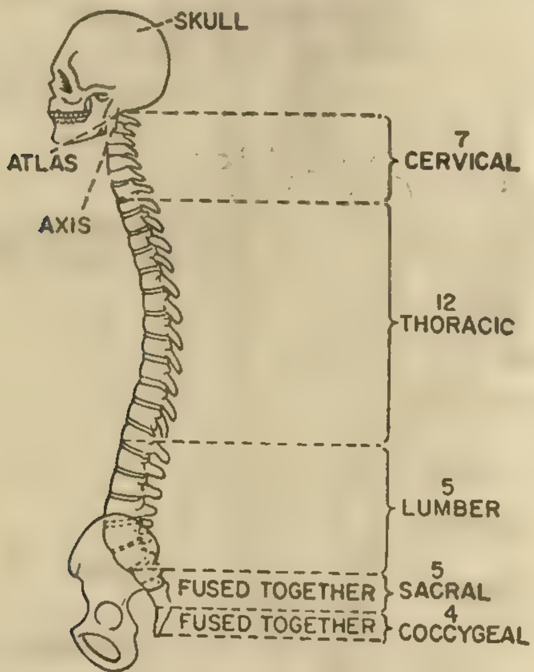


Fig. 36. Vertebral segments of human body.

Flat bones—These include the skull, sternum, scapula, ribs, pelvic bone and patellas. It protects mainly the delicate organs viz., brain, heart, lung and other visceral organs.

Irregular bones—The bones of the spinal column are mainly

of this category. These are the main constituents of Vertebral column. It consists of 7 cervical, 12 thoracic, 5 lumber, 5 sacral and 4 coccygeal (fused together). Cervical vertebrae support skull, allow rotation of head and neck. Thoracic vertebrae support ribs and allow movement of trunk. Lumber vertebrae allow backward and sideway movement. Sacral vertebrae transmit weight of body to pelvic girdle and legs. These are shown in fig. 36.

SKELETAL MUSCLES

The muscles account for approximately half the body weight and contain half the body water. Bones are moved at joints by the contraction and relaxation of muscles attached to them. The muscles associated with the skeleton are known as skeletal muscles and these are responsible for movements of the limbs and trunk. The functions of these muscles are mainly to supply the energy for any movement.

The anatomical locations of the various skeletal muscles are shown in figs. 37 and 38.

The location and function of various muscles are discussed in the following way :—

1. **Facial muscle**—These are present in the face and help in mastication, speech and facial expression.

2. **Pectoral muscle**—It is present in the breast and helps to bring arm in side and across chest.

3. **Thoracic muscle**—It is located inside the ribs and helps in respiration by contraction and relaxation.

4. **Abdominal muscle**—It is situated in abdomen. It protects internal delicate abdominal organs. It helps in micturition (Passing of urine), defaecation etc.

5. **Trapezius muscle**—It is present in the shoulder. It raises shoulder and pulls head back. This is also known as back muscles and helps in maintaining erect posture.

6. **Latissimus dorsi muscle**—This is situated below the trapezius in the back. It draws arm backwards and turns inwards. It also helps in erect posture.

7. **Deltoid muscle**—This is the arm muscle and helps in raising of arm.

8. **Triceps muscle**—This is also arm muscle and it straightens elbow.

9. **Biceps muscle**—This is arm muscle and helps in bending elbow.

10. Flexors of arm muscle—This is the muscles of forearm and bends wrist and fingers.

11. Extensors of arm muscle—This is also the muscles of forearm and it straightens wrist and fingers. (Flexors causes bending and Extensors causes straightening).

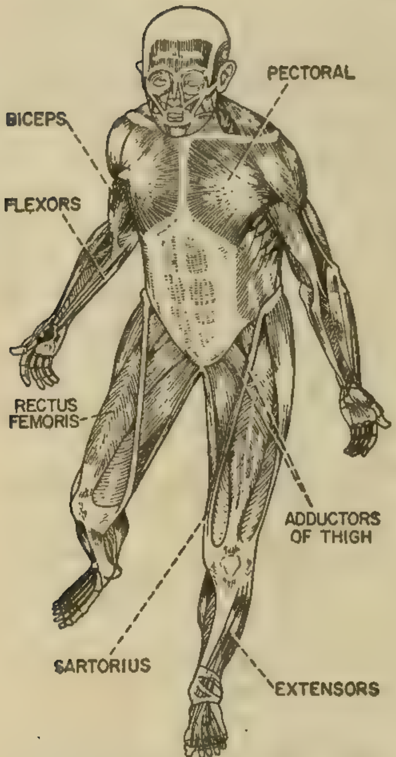


Fig. 37. (left) Skeletal muscles of human body in front view.

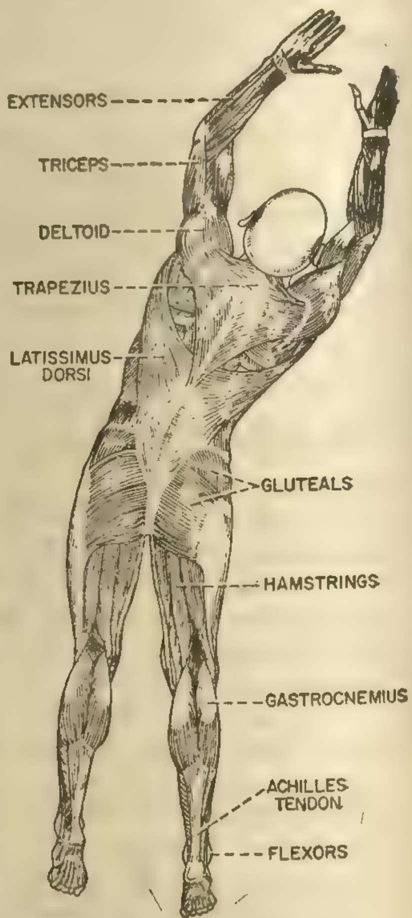


Fig. 38. (right) Skeletal muscles of human body in back view.

12. Gluteals muscle—It is a back muscle. It straightens hip joint and moves legs outwards.

13. Rectus femoris muscle—This is the muscle of thigh. This is most powerful muscles of the body. It bends hip joint and straightens knee.

14. Adductors of thigh—This is also the muscles of thigh. It moves the limb towards the midline and thus called adductors.

15. Sartorius muscle—This is another thigh muscle. It bends knee and hip joint. It turns thigh outwards from the midline and is called abductors.

16. Gastrocnemius muscle—This is leg muscle and is also powerful. It helps to bend knee and truns foot downwards.

17. Achilles tendon—It is situated in leg below the gastrocnemius. It helps in movement of foot.

18. Flexors of leg muscle—It turns foot and toes downwards.

19. Extensors of leg muscles—It turns foot and toes upward.

Rotation movement is performed by the activity of various muscles at a time.

JOINTS AND MOVEMENTS AS A PART OF LOCOMOTORY ORGANS

There are many different patterns of joint structure i.e., the articulations between the bones vary considerably as regards mobility in different parts of the skeleton. These are mainly the following types :

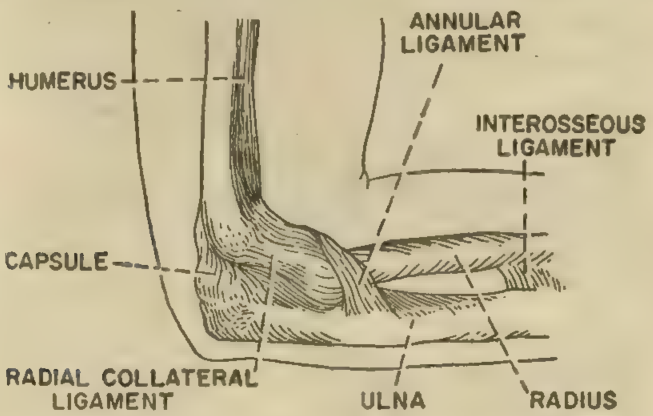


Fig. 39. Arrangements of ligaments between radius and ulna.

(1) *fibrous*, (2) *ligamentous*, (3) *cartilaginous*, and (4) *synovial joints*.

1. Fibrous—The edges of bones are united by means of a thin layer of fibrous tissue. No movements are permitted. The example is the sutures of the skull.

2. Ligmentous—Two bones, which may be adjacent or which may be quite widely separated, are tied together by one or more ligaments. These ligaments may be in the form of cords, bands or flat sheets. Example is the midunion of radius and ulna (fig. 39). The movement is usually limited and it is not any specific type.

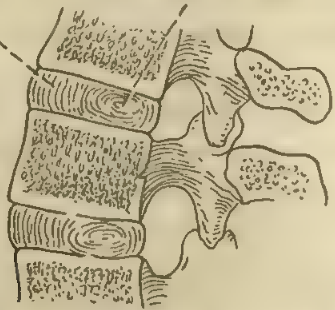


Fig. 40. Cartilaginous articulation of vertebrae.

3. Cartilaginous—The joints which are united by fibrocartilage permit motion of a bending and twisting nature. Examples are the articulations between the bodies of the vertebrae (fig. 40).

4. Synovial joints—This joint allows free movement. The bone ends are capped with smooth hyaline articular cartilage.

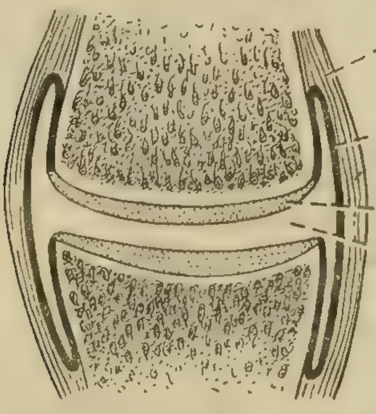


Fig. 41. Structure of the synovial joint.

The joint cavity is enclosed within the sleeve formed by the fibrous joint capsule; a sleeve stretching from one bone to the other is continuous with the periosteum. Ligaments of strong white fibrous

tissue hold the bone ends in apposition. The joint capsule is lined by a smooth, slippery synovial membrane which disappears at the periphery of the cartilage surfaces. This membrane is highly vascularised and secretes the lubricant synovial fluid, which covers the joint sufaces in a thin film. This is a clear viscid fluid which also nourishes the articular cartilage. This is shown in fig. 41.

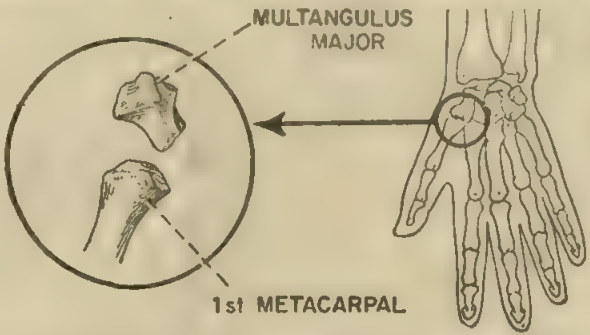


Fig. 42. Saddle joint between thumb metacarpal and the corresponding carpal bones.

Varieties of synovial joints—Synovial joints are further subdivided by virtue of the shape of their bone ends and the type of movements. These are the followings.

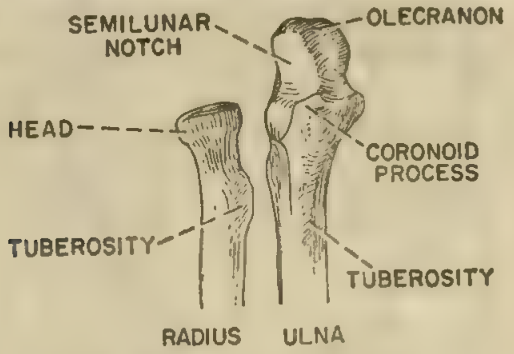


Fig. 43. Pivot joint between radius and ulna.

(a) *Plane joint*—The simple plane joint is the flat adjacent surface of carpal and tarsal bones. This allows minor gliding motion only.

(b) *Saddle joint*—It is saddle shaped surface. It is situated in between the thumb metacarpal and the corresponding carpal

bone. Fitting over this is a reciprocally concave—convex surface. Saddle joint has greater freedom of motion (fig. 42). This permits flexion and extension, abduction and adduction, and circumduction movements.

Fig. 44. Hinge joint in elbow.

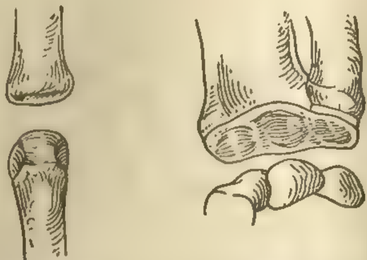


Fig. 45. Condyloid joint.

(c) *Pivot joint*—The pivot joint is formed with a cylindrical bone end rotating on its long axis like a hinge within its socket, e.g., the head of the radius at the superior radio ulnar joint at the elbow i.e., a small concave notch on one bone fits against the rounded surface of the other. It permits the rotation movement fig. 43.

(d) *Hinge joint*—One surface is pool like, the other is concave. The concave surface fits over the spool like process and glides partially around it in a hinge type of movement. Example is elbow joint (fig. 44). This causes movement in one plane about a single axis of motion. The movements are of flexion and extension.

(e) *Condyloid joint*—An oval or egg-shaped convex surface fits into a reciprocally shaped concave surface. Movement may be in two planes, foward and backward, and from side to side. Example are the metacarpophalengeal and radiocarpal (fig. 45).

(f) *Ball and socket joint*—In this type of joint, the spherical head of one bone fits into the cup or saucer like cavity of the other bone (fig. 46). Examples are hip joint and shoulder joint. It allows flexion and extension, abduction and adduction, circumduction and rotation. These are shown in fig. 47.

A SIMPLE MECHANISM OF MUSCULAR MOVEMENTS

The long bones particularly form a light frame work of lever. This lever is operated by the contraction of the skeletal muscles which are attached to it. Muscles become shorter when contract.

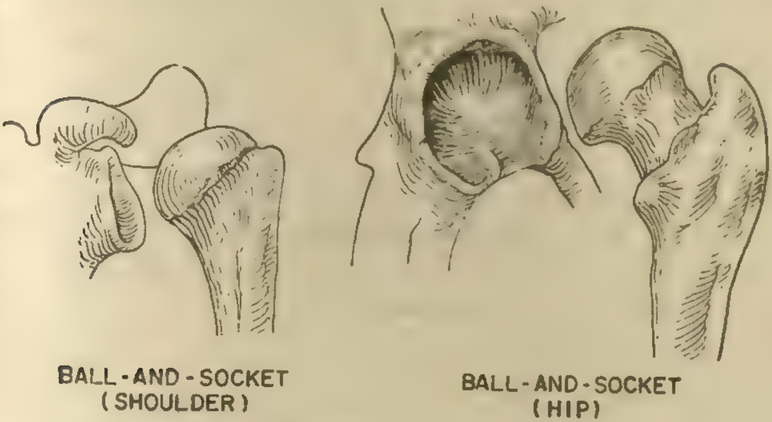


Fig. 46. Ball and socket joint in shoulder and hip.

Thus it brings its two ends closer together. Since the two ends are attached to different bones by tendons and this may cause their

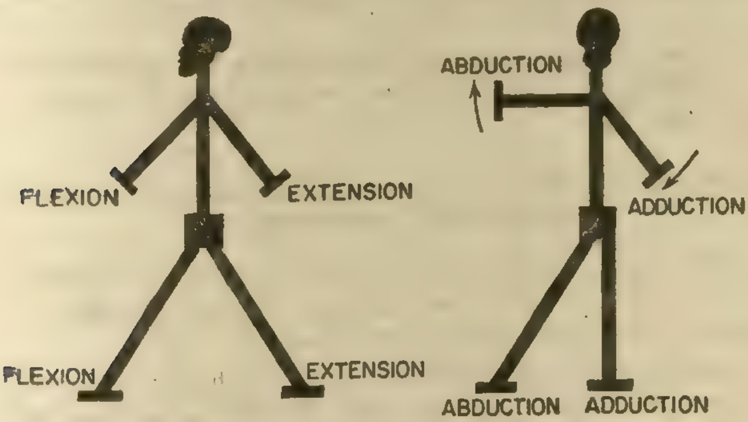


Fig. 47. Ball and socket joint with various kinds of movements.

respective movements. Two bones meet at a joint and the joint surface is covered with a layer of smooth cartilage. Synovial membrane secretes a lubricating fluid to avoid friction when the two surfaces of bones move on one another.

The muscles which contract to move the joint is called the

agonists e.g., the biceps in flexion of elbow. To allow the movement, other muscles near the joint must relax and are called the **antagonists** e.g., the triceps in flexion of the elbow.

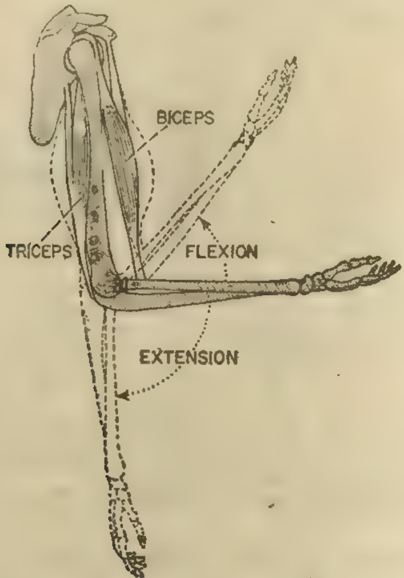


Fig. 48. A simple mechanism of nuscular movements.

During extension movement (straightening) the reverse occurs i.e., the triceps, the agonist contracts and the biceps, the antagonist relaxes. (fig. 48).

MUSCULOSKELETAL ORGANISATION INVOLVED IN LOCOMOTION AS WALKING

The shoulder gridle cooperates with the arm movements of the upper extremity while walking. Similarly the pelvic girdle cooperates in movements of the lower extremites.

The pelvic usually transmits the weight of the body alternately first over one limb, then over the other. Acetabulum simultaneously takes a favourable position for the action of corresponding femur. As the first one foot and then the other is put forward the flexion and extension movements of thigh are operated by a slight rotatory movements and abduction and adduction of the hips. It is also accompanied by slight lateral flexion and rotation of the spine.

The arms usually tend to swing in opposition to the legs. The left arm swings forward as the right leg swings forward and vice

versa. This is accomplished without obvious muscular action and serves to balance the rotation of the pelvis. It is a reflex action. Other opinion is that the deltoid muscles contract towards the end of forward swing and it serves as a break to check the movement. The middle deltoid is found to be active during both flexion and extension of the arm at the shoulder joint. Normally the arm swings exactly counterbalances the hip swings.

Walking has two phases. These are: (1) swinging and (2) supporting.

The swinging phase with toe-off and ends with heel-strike. The supporting phase begings with heel strike and ends with toe-off. In all parts of the supporting phase the contraction of the toe flexors is greater in barefoot walking than when shoes are worn. It is noticeable during walking on sand.

7

GENERAL PLAN OF THE HUMAN BODY—SYSTEMS & ORGANS

The general plans of the human body have already been discussed under various previous chapters. Only the endocrine system would be considered in the next chapters together with the special senses.

HISTOLOGICAL STRUCTURE OF VARIOUS TISSUE

Bone :—It is a connective tissue and it develops from mesoderm. This constituets the skeleton and is hardest of all connective tissue. It is made up of bone cells and intercellular ground substance. There are three types of bone cells. These are (1) Osteoblast, (2) Osteocyte and (3) Osteoclast. These are closely related with each other.

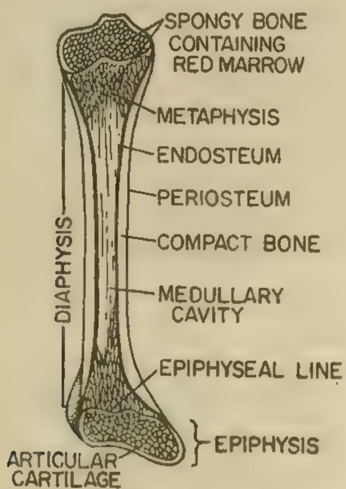


Fig. 49. Longitudinal section of a long bone (schematic diagram).

Osteoblast is concerned with bone formation and it is found in the growing surface where the bony matrix is deposited. This cell is strongly basophilic or pyramidal in shape. Its nucleus is

large. The cell secretes the bone matrix and thus calcification takes place.

Osteocyte is the trapped osteoblast within the matrix. This cell has small ovoid, highly chromatic nucleus. The osteocyte has got no active synthesizing property.

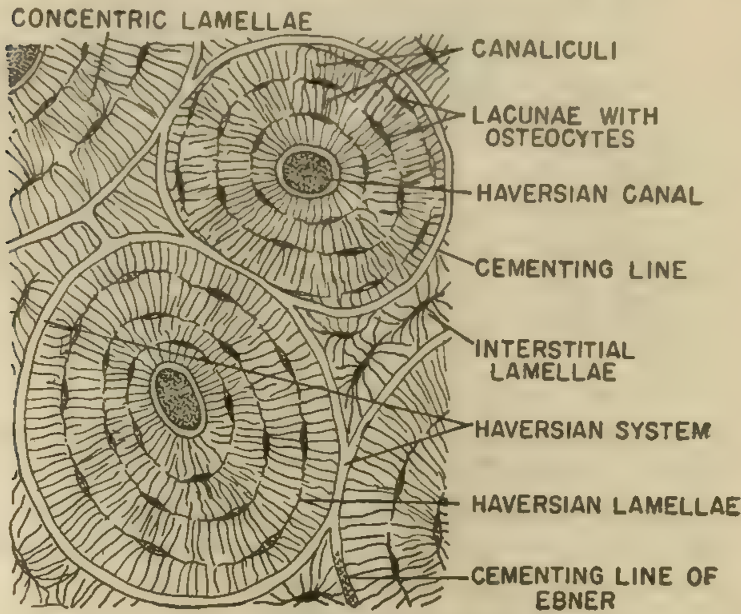


Fig. 50. Section of a compact bone.

Osteoclast is a giant bone cell with about more than 20 darkly stained nuclei. This cell helps in growth process and remodelling of bone. The histological structure of long bone and compact bone were shown in fig. 49 & 50 respectively.

Muscular tissue

The characteristic property of muscular tissue is its ability for contraction when excited. This is divided into three types of muscles. These are (1) *Skeletal*, (2) *Cardiac* and (3) *Smooth*.

1. **Skeletal :**—These are striated voluntary muscle (fig. 51). These are multinucleated cylindrical structure with longitudinal and cross-striation. This muscular tissue is responsible for mainly the voluntary movement of the living system.

2. **Cardiac :**—The cardiac muscle (involuntary striated) contracts rhythmically and automatically. This muscles form the muscle layer of heart.

It is shown in fig. 52. This muscle form a three dimensional network which causes the false syncytial appearance under light

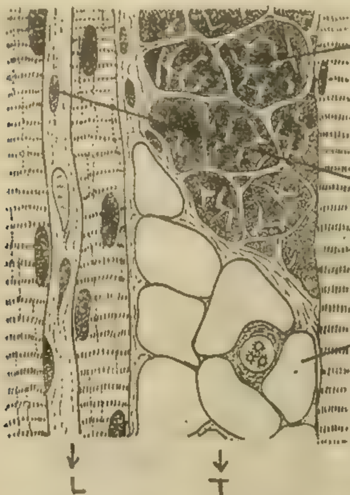


Fig. 51. Diagrammatic sectional view of voluntary muscles (L = Longitudinal T = transverse section).

microscope. The nucleus is single and placed deep in the sarcoplasm more or less at the centre. The sarcolemma of the cardiac muscle is more or less similar to skeletal muscle.

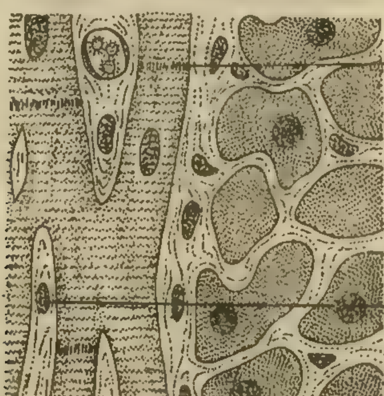


Fig. 52. Section of cardiac muscles.

3. **Smooth or Visceral muscle** :—The visceral muscle is also known as the plain, non-striated, smooth involuntary muscles. This muscle does not contract by will or volition. These are present

in the gastro-intestinal tract, ducts of glands, blood vessels, respiratory, urinogenital and lymphatic system of the body. It contracts

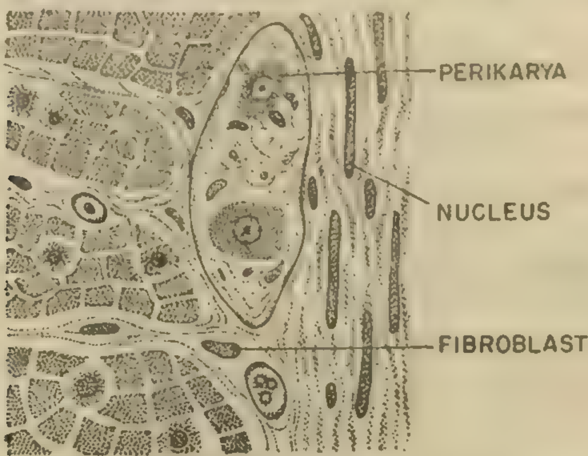


Fig. 53. Sectional view of visceral muscles.

automatically. The smooth muscle fibres are elongated, spindle-shaped and possess single nucleus. (See figs. 53 and 54). Longitudinal striations may be demonstrated by special preparation.

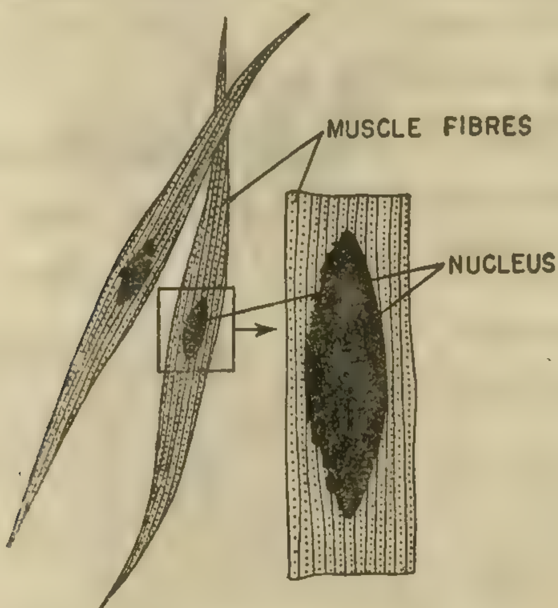


Fig. 54. Visceral muscle fibres.

Alimentary canal

The histological structure of the alimentary canal is given in figs. 55 and 56. The wall of the alimentary canal from the oesophagus

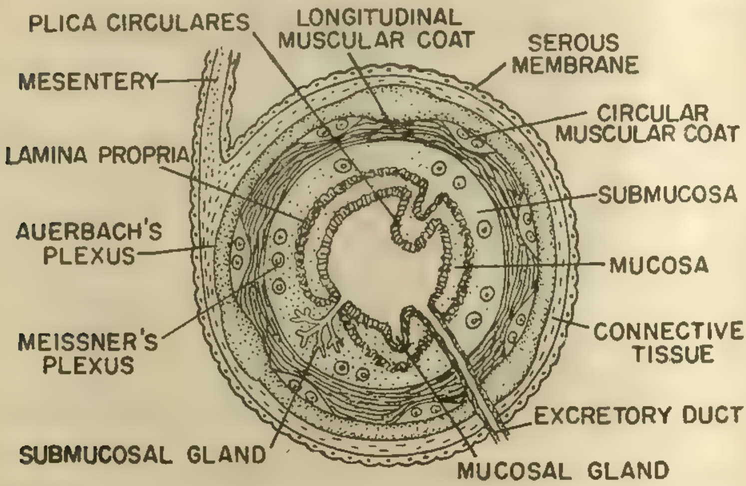


Fig. 55. Cross section of the alimentary tract.

to the anal canal consists of typical four encircling layers or tunics from outside inwards :—1. Serosa is a fibrous outer coat. 2. Tunica muscularies consists of double layer of smooth muscle. 3. Tunica

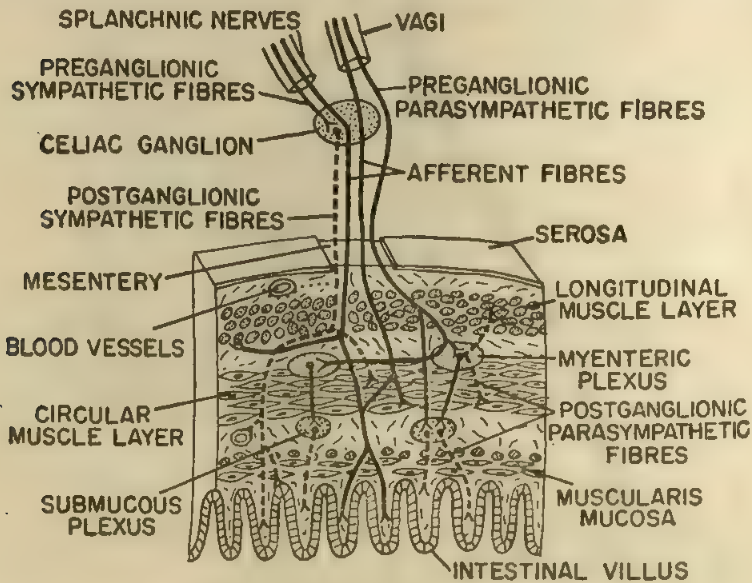


Fig. 56. Cross sectional view of intestinal tract.

submucosa is a loose areolar connective tissue layer which contains glands. 4. Tunica mucosa is known as mucous membrane.

Trachea and the lungs

These are shown in figs. 57 and 58. The trachea consists of a series of regularly spaced c-shaped hyaline cartilage and the open

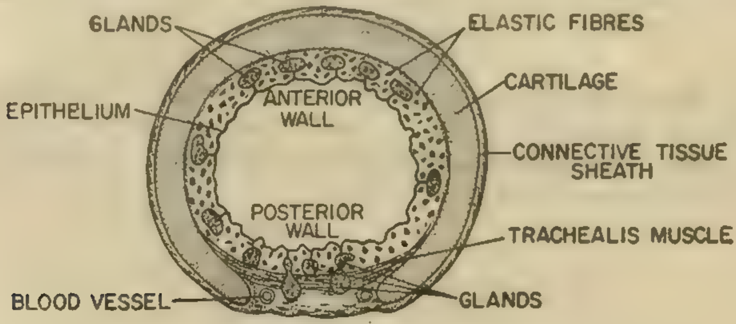


Fig. 57. Cross section through trachea.

segment is pointed posteriorly towards the running oesophagus. Structure of the lung shows a network of empty spaces surrounding by this walls, with bronchi, brononchioles and blood vessels.

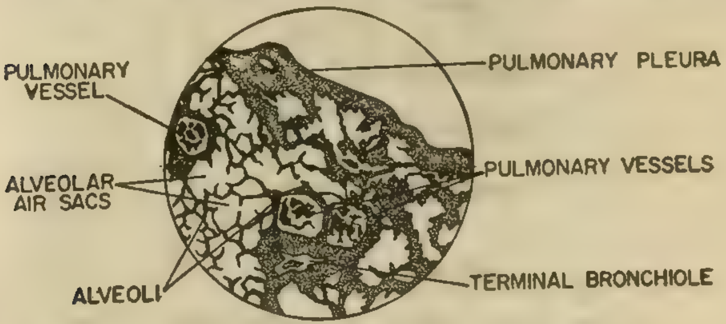


Fig. 58. Microscopical sectional view of human lungs.

Functional characteristic of epithelial connective, muscular and nervous tissue

The main function of the various tissue is (1) Protection against injury, (2) Absorption of various nutrients, (3) Secretion of various glands to perform various maintenance of the body, (4) Excretion is the main channel through which all the toxic and waste products pass away from the body to maintain normal health. The main functions of various tissue have already been described earlier.

8

NEUROENDOCRINAL CONTROL OF BODY AND SPECIAL SENSES

Distribution of Endocrine Glands :—The purpose of coordination by chemical messenger caused the development of endocrine glands. The engineering plan of the various endocrine glands are shown in figs. 59 and 60.

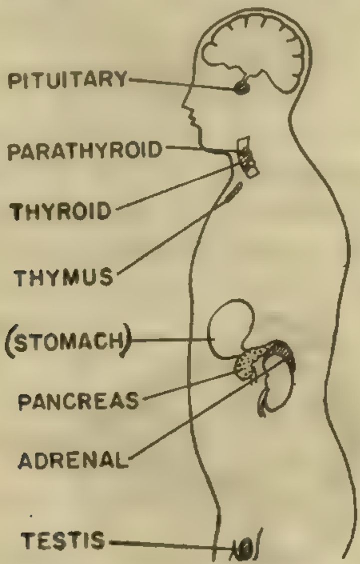


Fig. 59. Various Location of endocrine glands in male.

Endocrine glands are also called ductless gland. It is a chemical agent which is released from one group of cells and travel via the blood stream to affect one or more different groups of cells.

1. Nature and Functional way of Hormone :—

(A) It acts in low concentration and it is always a chemical compound.

(B) Hormones are not ordinarily stored except in the gland of origin.

(C) Hormones are usually destroyed and excreted as soon as their functions are over.

(D) Some hormones work quickly and are destroyed quickly i.e. epinephrine of adrenal gland.

(E) Dual control is also noted in some hormones i.e. there are many instances such as control of blood sugar, sex, and growth etc. where more than one hormone take part—some are helping the process and others are inhibiting it.

(F) Multiple secretions may be noted in some endocrine glands, e.g., pituitary, adrenal cortex etc.

(G) None of the endocrine glands is completely independent. These are closely interrelated and interdependent. The interrelationship may be synergistic or complementary or inhibitory. Thus some are antagonistic to others.

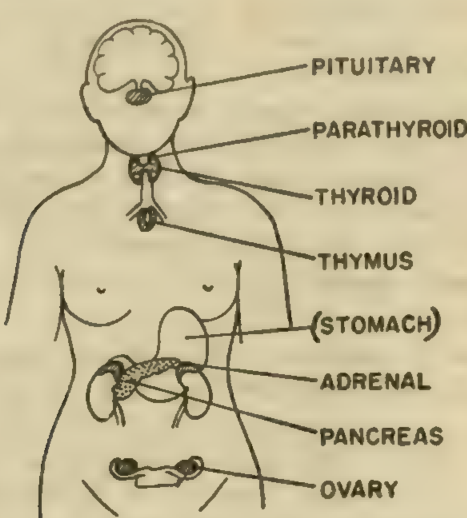


Fig. 60. Various locations of endocrine glands in female.

It is well known that a hormone often regulates its own secretion indirectly through other glands. This is known as feed back or push-pull mechanism. This may be a fundamental rule of endocrine regulation.

Anterior pituitary gland controls the activity of other endocrine glands and is known as band master to maintain harmony of body function.

HORMONAL REGULATION OF BLOOD GLUCOSE AND BLOOD CALCIUM LEVEL

Blood glucose :—Pancreas secretes two hormones : (1) Insulin & (2) Glucagon which help in maintenance of normal blood glucose

level. β-cells of Islet of Langerhans produces insulin which controls the normal blood sugar level.

Normal blood sugar level varies from 80-100 mg per 100 ml blood in fasting state. Blood sugar level is found to be 100-120 mg per 100 ml blood after meal. Following factors regulate normal blood sugar level

1. **Digestion of starch** :—It is a slow and long process. Absorption is also slow and thus a sharp rise in blood sugar is prevented.

2. **Rate of absorption** :—It is noted that about 1.84 gm per Kg per hour is absorbed. Whatever be the amount of sugar given, the rate of absorption of glucose does not exceed beyond it. The rate of utilization of sugar by tissues has nearly the same rate. 300-500 gm of glucose may be safely consumed and in most cases no glycosuria is observed.

3. **Role of liver** :—When blood sugar tends to rise, liver stores it as glycogen and when blood sugar tends to fall, liver mobilizes its glycogen stores and hastens the rate of gluconeogenesis from protein and fats and thus restors nomal blood sugar level. These processes are under the control of hormones.

4. **Role of muscles** :—Muscles also help in the same ways as did by livers.

5. **Role of hormones** :—The following hormones are the regulators of blood sugar level.

(a) *Insulin*—It is the main key to keep safe from the rise of blood sugar level. It lowers the blood sugar levels in three ways. These are : (i) by increasing glycogenesis, (ii) by promoting glucose uptake in muscles and adipose tissues, and (iii) by preventing gluconeogenesis.

(b) *Anterior pituitary* :—Growth hormone decreases peripheral utilization of glucose. The resulting hyperglycemia depresses β-cells to over production of Insulin.

Adrenocorticotrophic hormone (ACTH) and Thirotrophic hormone (TSH) through adrenal cortex and thyroid increase sugar level respectively.

(c) *Posterior pituitary* :—A large dose of oxytocin and vasopressin raises the blood sugar level.

(d) *Adrenal cortex* :—Glucocorticoids stimulate glycogenesis, depress the peripheral utilization of glucose. It increases gluconeogenesis in the liver.

(e) *Adrenal medulla*:—Epinephrine and norepinephrine increase the oxidation of glucose in the tissues.

(f) *Thyroid*:—It increases peripheral utilization of glucose in the tissues. It also stimulates glycogenolysis and gluconeogenesis.

(g) *Glucagon*:- It increases blood sugar by glycogenolysis and gluconeogenesis.

Thus it is found that all the important hormones take part in regulation of blood sugar level. Insulin fries to reduce blood sugar level whereas other hormones try to raise it. The normal sugar level is balanced by these two opposing forces and thus maintains optimum level of blood segar level. Insulin deficiency causes diabetes. In diabetes, diet control is important. Young diabetic patients may be relieved if they perform *exhaust muscular work* at least twice in a day because exhaust work causes a significant fall of blood sugar level. Thus exercise is also a therapy of diabetes.

Hormonal regulation of calcium level

Calcium is essential for the formation of bones and teeth. It is essential for the coagulation of blood, coagulation of milk and contraction of the heart muscles. Certain enzymes are activated by calcium.

Blood calcium varies from 9 to 11 mg per 100 ml of blood. This level is maintained as constant. A negative balance is found during hyperactive condition of thyroid and parathyroid and in deficiency of dietary calcium.

Control of calcium metabolism is governed by the hormones. These are :—

(A) *Parathyroid* :—It exerts the strongest influence on calcium metabolism. It mobilizes Ca^{++} from bone which is mediated by cyclic AMP.

(B) *Prostaglandin E_1* (PGE_1) :—It increases the level of cyclic AMP.

(C) *Adrenal cortex*:—Through phosporylation it helps indirectly the calcium metabolism.

(D) *Thyroid gland*:—It synthesizes the hormone thyrocalcitonin which lowers blood calcium level and antagonises the effect of parathyroid hormone.

(E) *Growth hormone*:—It increases the rate of bone formation and it acts opposite to those of the parathyroid hormone.

Thus calcium balance in blood is governed by the various hormones of which parathyroid hormone is of most important regulator.

NEUROENDOCRINAL CONTROL OF BODY TEMPERATURE

Heat production due to metabolism causes heat gain of the body. There is also some channels of heat loss from the body. Thus the mechanism by which body temperature is normally adjusted is known as the thermotaxis. The normal body temperature is 37°C which is maintained normally by many processes so that accumulation of heat in the body is prevented.

Mechanism of heat loss or maintenance of normal body temperature is governed by many forces and these are given below :

Heat is lost from the body by three channels. These are *skin*, *lungs* and *excretion*. Radiation, conduction, convection and evaporation are processes of heat loss from the body.

Neural regulation :—Nervous system controls both heat production and heat loss in the following way :

Hypothalamus :—The heat regulating centre lies in the hypothalamus. Hypothalamus exerts its effect by controlling autonomic nervous system and endocrinal systems.

Greater part of the thermal responses in visceral effectors are under the control of sympathetic nervous system. It causes the constriction of peripheral vessels.

Spinal cord is the connecting pathway between heat regulating centres in the hypothalamus, peripheral thermoreceptors and effector organs.

Endocrinal regulation :—Some of the endocrine glands also take part in heat production and heat loss.

(A) *Thyroid* :—Thyroxine stimulates BMR i.e., heat production. Cold stimulates and heat reduces thyroid secretion.

(B) *Adrenal medulla* :—Cold reflexly stimulates adrenaline secretion, which increases heat production by stimulating metabolism.

(C) *Adrenal contex* :—Adreno-corticoid secretion is stimulated by the increase or decrease of environmental temperature.

(D) *Anterior pituitary* :—TSH and ACTH of anterior pituitary hormone help in the maintenance of normal body temperature.

During exercise body temperature is increased. Body temperature is also increased where environmental temperature is too high and it causes heat stroke, where heat regulating mechanisms completely fail.

SPECIAL SENSES

The organs of special senses have special end organs for the reception of specific types of stimuli. There are four special sense organs. These are: (1) taste, (2) smell, (3) vision and (4) hearing.

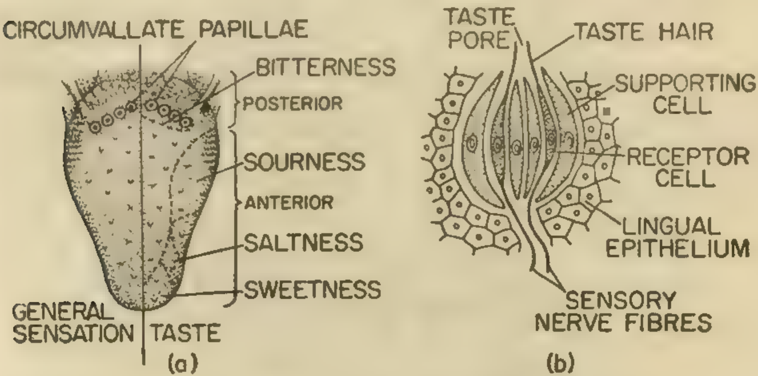


Fig. 61. Taste bud and its sectional view.

All are located in the head. The sense impressions are carried out by sensory nerves to the brain where the sensation is received and interpreted.

Taste organ :—Tongue is mainly concerned with the taste sensation. Taste buds are the end organs of taste. Taste receptors are considered as chemoreceptors. Receptors have microvilli covered with a polyelectrosurface film. The anterior two-thirds of the tongue is innervated by the lingual nerve and the posterior one-third is supplied by the glossopharyngeal nerve. The histological structure is shown in fig. 61. Primary taste sensations are: (1) sweet, (2) bitter, (3) sour, (4) salt. Each taste cell has got microvilli that are projected in the taste pore. Each bud contains a number of receptor cells whose apical tips project through a pore in the surface epithelium. Taste sensation is rapidly adapted and threshold of a stimulus for a particular agent is increased.

SMELL SENSATION

Like taste, smell also a chemical sensation. The substance of smell must be in gaseous form while the taste sensation is mediated

by the liquid substances. Through the nose the vapours get dissolved in the local secretion and stimulates the olfactory epithelium. The olfactory epithelium is that part of nasal epithelium which is sensitive to smell and confined to the nasal mucosa of the olfactory area. The histological structure of olfactory epithelium is shown in fig. 62.

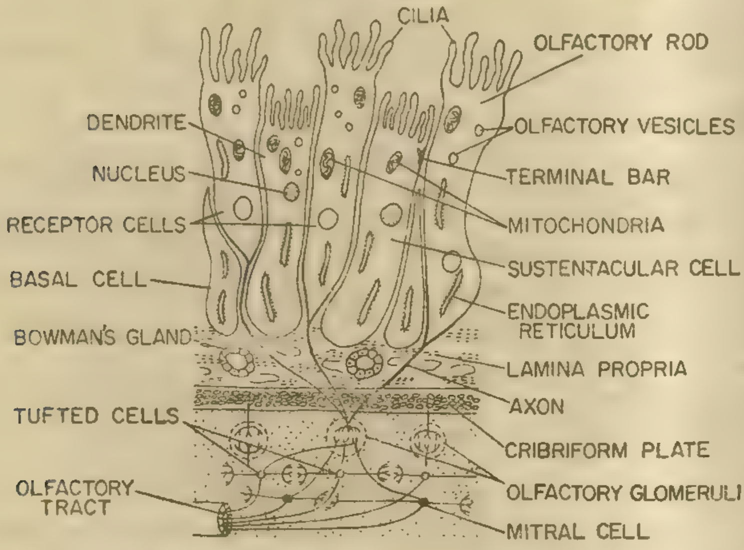


Fig. 62. Histological sructure of olfactory epithelium.

The olfactory epithelium is composed of mainly two types of cells. These are supporting cells and receptor cells. The supporting cells are highly columnar with large oval nuclei and ends in microvilli that secrete mucus. The receptor cells are bipolar neurones. Olfactory nerve controls the smell sensation.

VISION SENSATION

Eye is the vision sensation organ. The optic nerve controls the vision sensation. Structure of the eye is shown in fig. 63. From outside inwards, the wall has three coats : (a) Fibrous coat, (b) Vascular coat and (c) Nervous coat.

Fibrous coat has two parts : (1) posterior is opaque and called the sclera, (2) anterior is transparent, called the cornea.

The vascular coat has three parts : (1) the choroid remained just behind the retina, (2) the ciliary body and (3) the iris.

Nervous coat is called the *retina*. It contains the photosensitive receptors, where the visual impulses are generated.

Conjunctiva is the exposed part of the eyeball which is covered by a thin stratified mucus membrane. Its function is protection and lubrication.

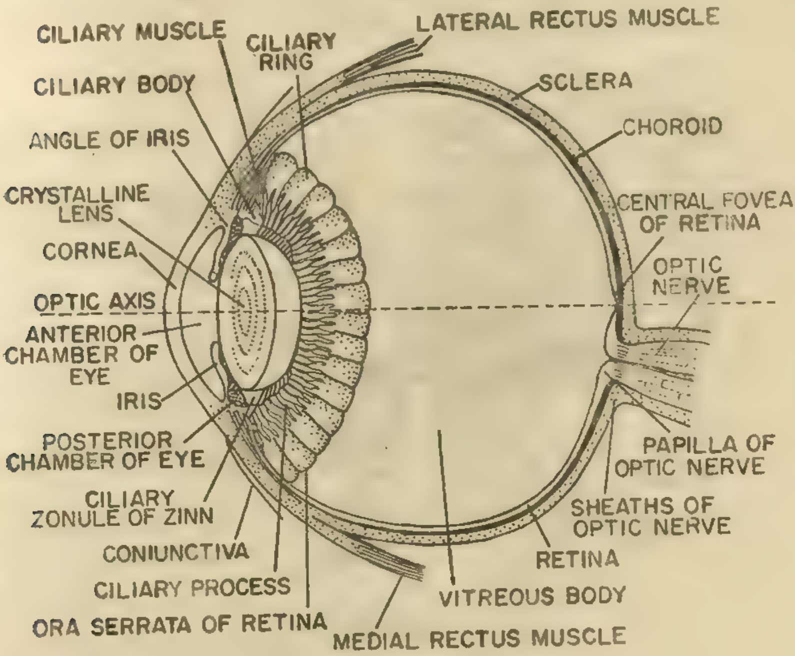


Fig. 63. Structure of the eye.

Crystalline lens is the chief refracting medium of the eyeball having the maximum refractory power. It is a transparent, elastic and biconvex lens, enclosed in a capsule.

Iris is a circular partition just in front of the lens. It has a central round aperture—pupil. The diameter of pupil can be altered. The iris behaves like a diaphragm. *The pupil in woman is larger than that in man.* The pupil modifies the amount of light entering the eye.

HEARING SENSATION

Ear is the sense organ of hearing. Ear has three parts: (1) external, (2) middle and (3) internal. Fig. 64 shows the diagram of ear.

External ear :—It has two parts : (1) pinna and (2) external auditory meatus.

Pinna collects and reflects sound waves into the meatus.

The external auditory meatus is a tortuous canal. It is shut off medially by the tympanic membrane. It transmits the sound waves perpendicularly to the membrane.

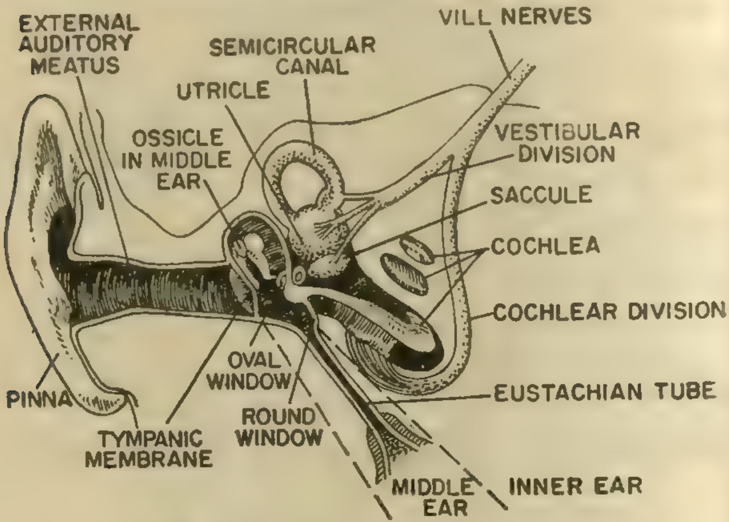


Fig. 64. Diagrammatic view of ear.

Middle ear contains air, auditory ossicles, tensor tympani muscle and stapidius muscle.

Internal ear has two parts : (1) cochlea (front), and (2) vestibular apparatus (behind). This is shown in fig. 65.

Cochlea is made up of bony canal, arranged spirally like the shell of a snail. The spirals wind round a central bony pillar called modiolus. The basilar membrane extends from the tip of the spiral lamina to the outer wall of the canal. A second membrane called Reissner's membrane stretches from the upper surface of the spiral lamina to the bony wall of the canal which is a little above the attachment of the basilar membrane.

The cochlear partition has been regarded as the mechanical frequency analyser of the ear.

If the intensity of sound is increased gradually above the threshold value the magnitude of sensation is increased and gives a painful sensation. It is called as threshold of feeling.

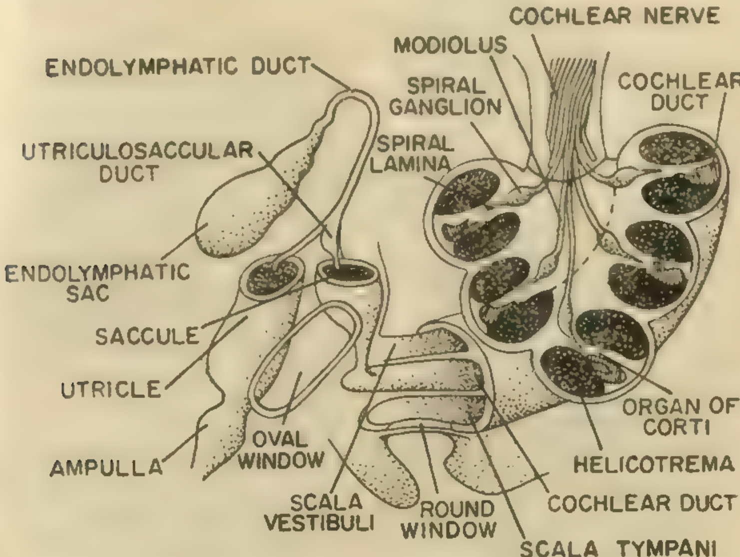


Fig. 65. Diagrammatic view of cochlea and the vestibular apparatus.

INDEX

BOTANY

ZOOLOGY

PHYSIOLOGY

TOPICS AND QUESTIONS FOR STUDY

(Part Two)

BOTANY

CHAPTER I. Virus

1. What is a virus? How viruses are classified according to the shape, type of nucleic acid and type of host?
2. Explain why viruses are called acellular organisms.
3. Describe the mode of infection of a bacterium by bacteriophage.
4. What is a bacteriophage? Describe its structure.
5. Distinguish between the structure of a virus and a bacterium.
6. Explain why a virus is called an obligate parasite.
7. Name several economically important plant diseases caused by viruses.
8. With the help of transduction how can you explain that DNA is the bearer of hereditary characters of an organism.
9. What are viruses and why is a study of viruses important? How does a virus differ from a bacterium structurally? Name at least two human diseases caused by viruses.
10. Write short notes on: (i) origin of virus; (ii) prophage; (iii) temperate phage; (iv) virulent phage; (v) capsid; (vi) deoxyvirus; (vii) ribovirus.

CHAPTER II. Bacteria

1. Why are bacteria considered as prokaryotes?
2. State the reasons why bacteria are regarded as plant rather than animal.
3. Describe the different methods of reproduction that occur in bacteria.
4. Bacteria are agents in soil fertility—Discuss.

   or

   Describe fully the importance of bacteria in the maintenance of soil fertility.
5. Name some autotrophic bacteria.
6. Characterise chemosynthetic bacteria as a whole and distinguish them from photosynthetic bacteria.
7. Describe several economically important diseases in plants as well as in animals caused by bacteria.
8. Name and describe some beneficial activities of bacteria.
9. How are bacteria classified according to their structures? Describe the structure of a bacterium. Give examples of two harmful and two beneficial bacteria.
10. Write short notes on: (i) obligate anaerobe, (ii) facultative anaerobe, (iii) zooglea stage, (iv) atrichous, (v) monotrichous, (vi) chemosynthesis, (vii) conjugation in bacteria, (viii) spirochetae.

CHAPTER III. Algae

1. What are algae? Describe the ecomonic importance of algae.
2. Describe the structure of *Oscillatoria* with special reference to its central body. Is it a procaryotic organism?
3. Describe the structure and reproduction of *Oscillatoria*.
4. Describe the vegetative structure and reproduction of *Chlamydomonas*.
5. Describe *Spirogyra* and its methods of reproduction.
6. Describe the life cycle of *Spirogyra* with a diagram indicating the points where changes of chromosome number take place.

7. Write short notes on:—
(1) centroplasm, (2) hormogonia, (3) palmella stage of *Chlamydomonas*, (4) pyrenoid, (5) scalariform conjugation, (6) lateral conjugation, (7) isogametes, (8) chromoplasm, (9) zygospore, (10) isogamy and (11) symbiosis.

CHAPTER IV. Fungi

1. How do you distinguish a fungus from an alga? How are fungi important in human life?
2. What is the economic significance of fungi?
3. Describe the process of sexual reproduction in *Mucor*.
4. Describe the life history of the fungus *Mucor*.
5. Describe different types of reproduction found in Yeast. What is alcoholic fermentation?
6. Give an account of the life history of *Penicillium*. Write what you know about the economic importance of some species of *Penicillium*.
7. What is meant by fruiting body? Draw a sketch of a mature fruiting body of *Agaricus* and mention its structural peculiarities.
8. Write short notes on:—
(1) mycelium, (2) penicillin, (3) coenocytic body, (4) sporangiophore, (5) columella, (6) cleistothecium, (7) hymenium, (8) basidium and (9) ascus.

CHAPTER V. Bryophytes

1. State the important characteristics of Bryophytes.
2. What is alternation of generations?
3. How do Bryophyte differ from Thallophyte?
4. What is alternation of generations? Illustrate the phenomenon in the life history of *Pogonatum*.
5. Give an account of the life history of *Pogonatum*.
6. Why is the sporophyte of the moss *Pogonatum* considered to be a parasite upon the gametophyte.
7. Describe the structure of the sporophyte of the moss *Pogonatum*.
8. Write short notes on: (i) rhizoid, (ii) archegonia, (iii) perichaetium, (iv) paraphyses, (v) antherozoid, (vi) calyptra, (vii) peristome, (viii) tympanum, (ix) columella, (x) operculum, (xi) protonema and (xii) seta.

CHAPTER VI. Pteridophytes

1. Name the class to which *Dryopteris* belongs. Describe the life cycle of *Dryopteris*.
2. Compare the life cycle of moss with the fern *Dryopteris*.
3. The fern prothallus is equivalent to what structure in the moss?
4. The fern plant with root, stem and leaves is equivalent to what structure in the moss?
5. Write short notes on: strobilus, sorus, annulus, prothallus, ramenta, indusium, stomium and neck cell.

CHAPTER VII. Gymnosperms

1. Describe the distinctive feature of gymnosperms.
2. Describe the life cycle of *Pinus* indicating critical stages.
3. What is the sporophyte of *Pinus* and what is its gametophyte? Compare the two with respect to size and independence.
4. Write short notes on: male cone, female cone, ovuliferous scale, heterospory, endosperm, cotyledon of Pinus, polyembryony.

CHAPTER VIII. Angiosperms

1. Describe the distinctive features of angiosperms.
2. What are monocotyledons? Compare dicotyledons with monocotyledons.
3. How many principal types of roots are present in the angiosperms?
4. Discuss the functions of roots.

5. What are underground stems? How are underground stems distinguished from roots?
6. What are stipules? Describe the different types of stipules present in plants.
7. What are the functions of stipules?
8. Distinguish between parallel venation and reticulate venation of leaves. Are these venation patterns considered in the identification of different kinds of plants?
9. Distinguish between simple and compound leaves.
10. What is phyllotaxy? Give an account of the principal types of phyllotaxy.
11. "Leaves are often modified in relation to some kind of functions." Explain with examples.
12. Name and describe the floral organs of a complete flower and state their functions.
13. Distinguish between complete and incomplete flowers.
14. Describe the flowers of china rose and pea.
15. What is a fruit? Describe different types of fruits.
16. Name the types of fruits and the edible portions of the following: mango, pineapple, litchi, cucumber, jackfruit, coconut, pea, apple, brinjal, black-berry and date.
17. Give an account of the pea plant.
18. Describe the rice plant from a rice grain to a mature plant.
19. Give an account of different forms of placentation.
20. Write short notes on: runner, tuber, offset, rhizome, corm, sucker, phylloclade, ligule, dorsiventral leaf, spine, bladder, monoecious, epigynous, perigynous, gamopetalous and spikelet.
21. What are stomata? Describe briefly their functions.
22. What is a vascular bundle? Name the different types of vascular bundles.
23. What is a stele? Draw sketches of different types of vascular bundles.
24. Based on the nature of anatomical structures state the distinguishing features of dicotyledonous and monocotyledonous stems.
25. Compare the anatomical structure of a dicotyledonous root with that of a monocotyledonous one.
26. Draw labelled diagrams of the transverse section of a young monocot and a young dicot stem.
27. What are dorsiventral leaves and isobilateral leaves? Compare the anatomical structure of a dorsiventral leaf with that of an isobilateral one.
28. Write short notes on: sub-stomatal chamber, bicollateral bundle, concentric vascular bundle, bundle cap, interfascicular cambium, protoxylem cavity, bundle sheath, annual ring, phellogen and lenticel.

ZOOLOGY

CHAPTER I. Outline Classification of Animal Kingdom.

1. Give an account of the salient features of the Phyla Echinodermata and Mollusca.
2. To which phylum, class, etc. do the following animals belong:— (i) *Paramaecium*, (ii) *Balanoglossus*, (iii) Prawn, (iv) Scorpion, (v) Pigeon, (vi) *Amoeba* (vii) *Hydra*, (viii) *Taenia*, (ix) Koi (*Anabas*), (x) Earthworm and (xi) Amphioxus.
3. In how many phyla the 'Invertebrate' or Non-chordate has been divided? What are they? Give examples. What are the salient features of these phyla?
4. What do you understand by vertebrate and invertebrate?

5. What is a phylum? Name and state the characteristics of major phyla of animal kingdom. Give two examples of each.
6. Mention the differences between Chordata and Nonchordata. Classify Chordata upto class giving examples in each case.
7. What are the characteristic features of Chordata? Give the general characters of Reptilia. Mention the names of few animals belonging to Reptilia.
8. Classify Chordata into classes with identifying characters and examples in each case.
9. "All vertebrates are chrodates but all chordates are not vertebrates."—Explain.
10. Describe the characteristic features of Mammalia. Name five animals belonging to Mammalia.
11. What are the scientific names of (i) toad, (ii) lizard, (iii) tapeworm, (iv) koi fish, (v) pigeon, (vi) earthworm and (vii) man?

CHAPTER II. Structure and functions of Amoeba, Tapeworm and Guineapig

Amoeba

1. Describe *Amoeba* with properly labelled sketches. Describe its nutrition and locomotion.
2. How does an *Amoeba* moves?
3. In which phylum *Amoeba* belongs? Describe the methods of reproduction in *Amoeba*.
4. What is a food vacuole? In which animal it is found?
5. Which animal is involved in causing dysentery?
6. Write short notes on:—
   (i) Pseudopodia, (ii) Binary fission, (iii) Multiple fission, (iv) Cyst, (v) Contractile vacuole, (vi) Food vacuole.

Tapeworm

1. Describe the structure and life history of tapeworm.
2. What is the scientific name of tapeworm? Describe its structure.
3. Describe the reproductive system of tapeworm.
4. Mention the parasitic adaptations in tapeworm.
5. Describe the excretory system of *Taenia solium*.
6. What is a scolex? State its function.
7. Write short notes on:—
   (i) Proscolex, (ii) Hexacanth, (iii) Cysticercus, (iv) Oncosphere, (v) Bladderworm, (vi) Proglottis.

Guineapig

1. Describe the external structure of guineapig.
2. What is the scientific name of guineapig? Give an illustrated account of the skull of guineapig.
3. Mention the place of occurrence and functions of the following:—
   (i) Ilium, (ii) Portal vein, (ii) Systemic vein.
4. Describe the digestive system of guineapig.
5. Describe the respiratory system of guineapig.
6. Describe the structure of the heart of guineapig and mention the course of blood circulation through the heart.
7. Describe the arterial system of guineapig.
8. What is reproduction? Describe the female reproductive system of guineapig.
9. What is a unisexual animal? Describe the genital organs of male guineapig.
10. Write short notes on: (i) Atlas and (ii) Dental formula.

CHAPTER III. Economic Zoology

1. Define economic zoology.

Sericulture

2. What is sericulture? Name the places where sericulture is practised in India. What are the problems of sericulture?
3. Write a brief essay on sericulture.
4. Give the scientific name of silkworm. How silk is obtained?
5. How silkworms are reared? Give the history of the silkworm.
6. Where silk moths are cultivated in India? What is meant by spun silk and reeled silk?
7. Give the scientific names of two types of silkworm moth of India. What is silk? How and when it is collected? Name two diseases of silk moth.
8. Name different types of silk with names of the silk moth for the respective types. Which stage in the life cycle of silk moth is important for silk production?
9. Give the names of various diseases of silk moth.

Apiculture

1. Write in short what do you know about apiculture. Describe the social life of honey bee.
2. Name few plants from where honey-bee can get honey or pollen.
3. Describe methods of bee-keeping.
4. Discuss about the various diseases of honey-bee.
5. What is honey? How is it formed? Give scientific name of a honey-bee.
6. Write short notes on: (i) Artificial bee-keeping, (ii) Swarming, (iii) forager's dance, (iv) Beehive, (v) Nuptial flight and (vi) Royal jelly.

CHAPTER IV. Medical Zoology

Mosquito

1. 'Mosquito is a harmful animal'—Justify. How it can be controlled?
2. Compare the larval stages of *Anopheles* and *Culex*.
3. Distinguish between eggs, larva, pupa and adults of *Anopheles* and *Culex* mosquitoes. Mention two diseases caused by mosquitoes. What is the scientific name of filarial worm?
4. Name the mosquito which carries filarial worm. How can you distinguish it from the malarial germ carrying mosquito? Briefly state the mode of transmission of malarial parasite.
5. Discuss the medical importance of mosquitoes.
6. Name the diseases caused by *Anopheles*, *Culex* and *Ades* mosquitoes.
7. Describe in brief the life history of a mosquito. Which mosquitoes (male or female) can suck blood?

CHAPTER V. Agricultural Zoology

1. What is meant by agricultural zoology?

Pisciculture

2. What is pisciculture? How is carp culture done?
3. Write a short essay on pisciculture. Give scientific names of two most common carp fishes.
4. What are the differences between inland and marine fisheries?
5. What is meant by hypophysation?
6. How is carp breeding done in a pond?

Pests of Paddy

7. What is pest? Name two paddy pests. How they attack the paddy plants? How they can be controlled?

8. Name the important paddy pests. Give the scientific name of any one of them. When it attacks paddy plants? Give its life history. How it can be controlled?
9. Name one paddy pest. Mention the stage when the paddy is attacked, symptoms of damage, period of infestation. State the various methods of control of this pest.

Stored grain pests

10. Name the stored grain pests and state the damage done by any one of them and control measures.

CHAPTER VI *A knowledge about important wild animals. Methods of conservation of Tiger and Rhinoceros*

1. What are the important wild animals which are becoming extinct?
2. Discuss the importance of wild life.
3. Name two wild animals and describe their characteristic features.
4. What are the causes of extinction of many wild animals in recent time? How wild animals can be preserved?
5. What is conservation? Discuss the methods of wild life conservation. Name one bird sanctuary in West Bengal.
6. Name and state the location of four wild life sancturies of India:
7. What is meant by wild life? Name four Indian animals which are on the way of extinction. State the methods of conservation of Rhinoceros.
8. What are the causes of decrease in number of Rhinoceros?
9. What are the causes of considerable decrease in number of Tigers? What measures have been taken to protect tigers?
10. What do you know about the conservation of Tiger or Rhinoceros?

PHYSIOLOGY

CHAPTER I. Food and Metabolism

1. Describe the principal constituents of human diet. What are the biological values of protein and protein efficiency ratio? Cite some figures of common food stuffs.
2. What is balanced diet?
3. Describe the calories requirements of man and woman. What is the principles of preparation of a balanced diet?
4. Describe the biochemical composition of some common foods which we need daily in our diets.
5. Compare vegetarian and non-vegetarian diets in adult.
6. Describe the digestion of carbohydrate or protein or fat with the mechanism of absorption in the alimentary canal.
7. How carbohydrate is metabolised after absorption in the alimentary canal.
8. What is glycolysis and describe the stages in brief.
9. Describe citric acid cycle or Krebs' cycle. How many mols of ATP are the net gain of the break down of glucose to CO_2 and H_2O?
10. What is Cori Cycle?
11. What do you know about Glycogenesis, Glycogenolysis and Gluconeogenesis?
12. What is normal blood glucose level? Does deficiency of insulin cause diabetes?
13. Describe in brief the process of metabolism of fat or lipid.
14. Describe protein metabolism. What is fate & functions of protein metabolism?
15. Describe what do you mean by Transamination, Amination, and Deamination.

16. What is Transmethylation? Describe the nucleoprotein metabolism.
17. What is aminoacid pool in the body?

CHAPTER II. Transport of Nutrients and Gases in the body

1. Describe the composition and functions of blood.
2. Give a brief account on RBC, WBC and Haemoglobin.
3. What is lymph? Give an account of composition and function of lymph.
4. Describe the course of circulation of blood through the human heart with diagram.
5. What do you mean by cardiac output? How it is determined?
6. Describe the mechanism involved in internal and external respiration.
7. Describe the structure of the respiratory organs in man.
8. Describe the mechanism involved in inspiratory and expiratory movements. How the different respiratory muscles are involved in respiration?
9. What do you mean by the various compartments of lung air?
10. How you will measure and define Tidal volume, Inspiratory capacity, Expiratory Reserve volume, Residual volume, Vital capacity, Functional Residual capacity and Total lung capacity.
11. Compare & describe why the compositions of inspired, expired and alveolar air are different.
12. What do you mean by R Q and VD?

CHAPTER III. Neurophysiological control of body

1. What do you mean by receptors? How these are classified?
2. Describe the function and properties of the receptors.
3. Describe the structure & function of neurone or synapse.
4. Describe the structure of the motor end plate (or neuro muscular junction). What is the transmitter of neuromuscular junction?
5. What do you know by Reflex action? Describe the pathway of reflex
6. Describe the general characteristics of reflex action. action.
7. What do you know about central nervous system?
8. Describe the structure and function of spinal cord.
9. Describe cerebral cortex and its important function.
10. Describe the important functions of thalamus and hypothalamus.
11. Describe the functions of cerebellum and medulla oblongata.
12. What do you know about peripheral nervous system?
13. Describe the cranial nervous system & their functions.
14. What do you mean by Autonomic Nervous system?
15. Describe the functions of autonomic nervous system.
16. Does sympathetic and parasympathetic nervous system mean autonomic nervous system?
17. Describe how autonomic nervous systems have been classified.

CHAPTER IV. Excretion of Metabolites

1. Describe the structure and function of kidney.
1. What do you know by nephron? Describe its structure with various parts & give a brief account of their functions.
3. Give an account of the general functions of nephrons.
4. Show normal and abnormal constituents of urine.
5. Describe what are the abnormal constituents of urine.
6. Describe the excretory function through lungs and skin.
7. Describe the structure of sweat gland with its main functions in the body.

CHAPTER V. Reproductive Physiology

1. Describe the structure and function of male reproductive organs.
2. Give an account of the histological structures of the testis and their main functions.
3. Describe what is spermatogenesis and show a diagram of a spermatozoon with its various parts.
4. Describe the structure and function of female reproductive organs.
5. Describe the structure of ovary & their functions.

6. What do you know by gametogenesis of ovum.
7. What is ovulation ?
8. Describe the various stages of Menstrution cycle.
9. Describe the role of various hormones which controls menstruation.
10. What is called fertilisation ? How ovum fixes in the endometrium after conjugation.
11. What do you know by the safe period of woman ? How ovulation is counted ?
12. Describe the various techniques of family planning.
13. Give a brief account on the control of fertility and population.
14. Write short notes on :—
    (a) Uterus, (b) Ovum, (c) Testis, (d) Ovulation, (e) Corpus luteum, (f) Abortion, (g) IUCD, (h) Vesectomy, (i) Tubectomy, (j) Oral contraceptives.

CHAPTER VI. Musculo-Skeletal System-Locomotion

1. Describe the compositon of musculo-skeletal system.
2. What do you know about bone, muscle, tendon and ligaments ?
3. Describe the skeleton system of human body.
4. What do you know about various skeletal muscles in human system ?
5. Give a brief account on the joints and movements of various skeletal systems.
6. Describe a simple mechanism of muscular movements.
7. What do you know about Flexion, Extension, Abduction, Adduction in muscular movements ?
8. Describe how musculoskeletal organisation involved in locomotion as walking.
9. Give an account of short notes on: (a) Tendon, (b) Ligament, (c) Long bone, (d) Short bones, (e) Flat bones, (f) Synovial joints and its varieties.

CHAPTER VII. General plan of the human body.

1. Describe the histological structure of bones.
2. Describe the histological structure of various muscular tissue.
3. Describe the histological structure of the alimentary canal.
4. Describe the histlogical structure of trachea and the lungs.

CHAPTER VIII. Neuroendocrinal system and special senses.

1. Describe the distribution of endocrine glands with its nature and functional mechanism.
2. Describe the hormonal regulation of blood glucose (or sugar) level in the body.
3. Describe the normonal regulation of calcium level in the body.
4. Describe the structure and function of various special senses.